ILLINOIS NATURAL HISTORY SURVEY

INSTITUTE OF NATURAL RESOURCE SUSTAINABILITY
UNIVERSITY OF ILLINOIS

ANNUAL PROGRESS REPORT

FACTORS INFLUENCING LARGEMOUTH BASS RECRUITMENT: IMPLICATIONS FOR THE ILLINOIS MANAGEMENT AND STOCKING PROGRAM

M.J. Diana, M.A. Nannini, A.J. Pope, C.S. Deboom, J.J. Mulhollem,
D.P. Philipp, and D.H. Wahl

Submitted to
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Illinois Department of Natural Resources
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Disclaimer:
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EXECUTIVE SUMMARY:

During the past segment, all activities outlined in the annual work plan were accomplished and within the specified budget. The goal of this study is to develop management strategies that maximize growth, recruitment, and harvest of largemouth bass *Micropterus salmoides* in Illinois impoundments. Largemouth bass are frequently stocked in many Illinois impoundments to compensate for variable recruitment. Even so, the long-term contribution of stocked fish to recruitment and harvest of natural bass populations is unknown and we are addressing these questions. In addition, information on the importance of rearing technique, size of stocked fish, forage base, cover, resident predators, physical-chemical conditions, and stocking stress in determining largemouth bass stocking success is needed to optimize use of hatchery produced fish. Because stocking is only one of several management options for this species, it is critical that additional information on factors limiting recruitment processes be identified.

There was no new activity in Job 101.1 as final recommendations were presented in previous reports. In Job 101.2, we continued our evaluation of stocking success of largemouth bass. We concluded a study comparing intensive and extensive rearing techniques. Intensively reared fish were raised in raceways and fed pellets, where as extensively reared fish were raised in ponds and fed zooplankton and minnows. Extensively reared fish experienced better survival through the spring following stocking, but by the following fall (age-1) there was no difference in abundance between the two rearing techniques. Cost of rearing was much higher for the extensively reared fish for both hatchery ponds and lake side rearing facilities. Higher initial survival and larger size in the fall of extensively reared fish initially appears to justify the added cost. However, long term survival was low for both rearing types and very few stocked fish were recruited to the fishery. In this segment, we also continued to evaluate different stocking techniques to improve survival of stocked largemouth bass. Three lakes were stocked with largemouth bass, with half the fish stocked at the boat ramp and half dispersed throughout the lake and into woody or vegetated habitat. Very few stocked fish have been recaptured from any stockings conducted thus far regardless of method. We plan to continue additional stockings and adjust stocking time to minimize high temperatures and potential related mortality. CPUE of stocked fish in this experiment has been lower than observed in stockings conducted as part of this project and we hope to observe greater survival in the future in order to evaluate the success of these two stocking strategies.

In this segment, we also continued to examine changes in fish populations resulting from supplemental stocking of largemouth bass. We examined 13 lakes over an 8 year period where each lake was stocked with largemouth bass fingerlings. In lakes where gizzard shad were absent we found that increased piscivory from stocked fish significantly reduced small bodied and juvenile fish density. There was little effect on adult populations of prey fish that were comprised mostly of bluegill. Due to their ability to outgrow the gape limitation of predators and associated behavioral and physical anti-predator adaptations, bluegill appear to limit the effectiveness of biomanipulation via predator enhancement in these systems. Gizzard shad dominated lakes also exhibited a lack of fish community responses to piscivore enhancement and suggests that this species may also not be subject to consumer control by largemouth bass. While our results demonstrate a degree of resilience in the aquatic communities of Illinois lakes to predator effects we caution that managers should not ignore the potential impacts of supplemental largemouth bass stockings on prey fish communities.

In Job 101.3, we evaluated the survival and reproductive success of stocked largemouth bass relative to resident populations. To determine the contribution of stocked fish, the MDH B2B2 allele was used as a genetic tag for fingerlings stocked into six study lakes. Once these fish were part of the reproducing population, it was possible to assess the reproductive success and recruitment of these stocked fish in five of the six lakes by comparing the pre-stocking with post stocking MDH B2 allele frequencies. We also looked at lake size as a possible factor that may have influenced reproductive success. Stocked fish survival to adulthood was variable in the five study lakes, ranging from less than 10% to around 35%. Stocking contribution was also variable and was high in small lakes, but relatively low in larger ones. Based on the proportion of stocked adults in the populations we could predict the change in the frequency of the MDH B2 allele to determine how reproductive success of stocked fish compared to wild fish. We found that reproductive success of stocked fish was similar to wild fish. Our results indicate that stocking is most likely to be successful in small lakes and that the genetic influence of stocked fish will persist in successive generations. In future reports, we will examine how prey availability and overall adult largemouth bass density could affect stocked largemouth bass condition and ability to secure good nesting sites differently than wild fish.

In Job 101.4, we continued a multi lake experiment examining the influence of vegetation on largemouth bass recruitment. Lakes were divided into treatments by the vegetation management strategy. Two lakes (Stillwater and Airport) were treated for vegetation in an effort to reduce the vegetation present and yield more intermediate vegetation densities. The vegetation treatments were initiated in this segment and will be evaluated in the future. Two lakes (Paradise and Dolan) experienced management to increase vegetation. Vegetation planting was initiated in 2008 and planting efforts continued in this segment. We are to evaluating the success of different species of vegetation and the size of cage used. American pondweed has shown the greatest long-term survival and the large cages have been most effective in producing vegetation. In this segment, American pondweed was planted in 11 large cages and 20 small cages and wild celery was planted in 12 large cages and 33 small cages. We also evaluated fish and invertebrate communities associated with vegetated and non vegetated cages and observed higher densities of both fish and invertebrates in vegetated cages. Four lakes with experimental treatments and 9 control lakes were monitored for fish populations, vegetation densities, and prey organisms and will be compared through this time as the management experiment continues.

In this segment, we also continue to examine patterns in abundance of young-of-year largemouth bass, other fish species, and associated biotic communities among vegetated, woody, and open lakeshore habitat types in two Illinois lakes. We did not find significant differences in age-0 largemouth bass densities among the microhabitat types sampled in our enclosure surveys, however we did find significant differences in the community composition and abundance of potentially important prey items. Inshore prey communities are denser in both wood and vegetated habitat and these areas should be beneficial to fish. We also conducted two trials of a pond experiment (in one tenth acre pond) designed to examine the importance of woody habitat to fish communities were conducted at the Sam Parr Biological Station. Five ponds were stocked with wood and 5 ponds were left with no wood. In the first experiment, bluegill, golden shiner, and largemouth bass were stocked in each pond and observed through summer to monitor growth and survival. In the second experiment, 5 largemouth bass were stocked in each pond along with bluegill of small sizes vulnerable to predation, and larger size that were not vulnerable to prey and monitored overwinter for differences in growth and mortality. In the first experiment, we found evidence that the presence of coarse woody habitat can increase growth of bluegill in a simple aquatic community. The findings of the overwinter experiment were consistent with those of the summer pond experiment though with a somewhat weaker effect. In addition, both field observations and our pond study indicate coarse wood was associated with increased abundance of cyclopoid copepods. Taxa specific increases in benthic productivity may have important implications for growth and survival of juvenile fishes inhabiting the littoral zone and may explain the observed increases in bluegill growth.

There is potential for dam escapement to influence largemouth bass recruitment. In order to access dam escapement, we sampled downstream of the dam on two reservoirs, Ridge Lake and Forbes Lake via backpack electrofishing and seines. Some largemouth bass were observed in sampling below the dam at both Forbes and Ridge Lake following high water events however there were few fish in all sampling. The assessment of dam escapement is in the very early stages of implementation and evaluation and much more data is needed to draw conclusions about the effect of escapement on largemouth bass populations and recruitment. Additional data will be collected so that a baseline can be established in order to compare largemouth bass numbers after an increased discharge event to largemouth bass numbers during low flow periods.

There is potential for angling to have a large influence on largemouth bass populations. In particular, competitive tournament fishing for black bass has grown rapidly over the past several years. Previous work has shown high levels of mortality associated with these tournaments in other parts of the United States. However, little is known about the effects of tournaments on largemouth bass recruitment. In job 101.5, we continued to examine effects of tournaments for largemouth bass. In this segment, we continued monitoring largemouth bass spawning activities at Lincoln Trail Lake. Largemouth bass appeared to prefer cobble, pebble and gravel nesting substrates, while avoiding vegetation and detritus. We also continued one and initiated a second pond experiment examining the population effects of early broods and tournament angling on largemouth bass populations. Ponds that had the early cohort removed had approximately 5 times greater recruitment than ponds with the early cohort intact. In future segments, we will include data collected from both pond experiments once the second experiment has concluded and samples from both ponds are processed. In this segment, also we continued to conduct largemouth bass tournaments in alternating years on Ridge Lake to evaluate their effect on recruitment. A series of spring tournaments were conducted in 2007 and 2010 and largemouth bass populations were compared among tournament and non-tournament years. Initial results showed greater recruitment in 2007 compared to non-tournament years. These results are preliminary and additional years will be needed to evaluate treatment effects. Thus far, spring tournaments have not had an adverse affect on recruitment of largemouth bass. In this segment, we conducted an additional paper tournament and included it in the evaluation of the potential for these style tournaments. Paper tournaments provide an alternative format to weigh-ins which add a good deal of stress to largemouth bass and can create both lethal and sublethal effects (see previous segments). Paper tournaments evaluated thus far have resulted in similar ranking of anglers as with traditional weigh in with the mean change in rank of only 1.1 rank. In addition, paper tournaments allow directors to evaluate the catch of fish that are not legal to harvest and allow for some alternate measures of angling skill. In this segment we also continued to evaluate tournament activity on a number of Illinois lakes. Twelve lakes were categorized into no tournament pressure, medium tournament pressure and high tournament pressure. Preliminary analysis showed greater recruitment on no tournament lakes but lower densities of adult largemouth bass greater than 14 inches. We will continue to collect tournament and weigh-in data and examine relationships between tournament angling and fish populations.

In Job 101.6, a portion of Clinton Lake that was closed to fishing was sampled to continue assessment of the effects of a refuge on largemouth bass populations. Electrofishing samples yielded a higher abundance of adult largemouth bass in the refuge than in the main lake. Some increase in the number of largemouth bass has also been observed throughout the lake. Sampling will continue at Clinton Lake to monitor largemouth bass populations for changes resulting from the refuge. We also continued sampling Otter Lake as an additional location to evaluate refuges. Electrofishing and seine samples were conducted in two proposed refuge sites as well as three control sites. The refuge was closed to fishing in June 2010 and we will begin to sample for post refuge data and report findings in future segments. We also began assessing effects of harvest regulations on largemouth bass populations. In this segment, we developed a database from the Fisheries Analysis System (FAS) containing electrofishing data collected by DNR biologists. We grouped lakes by regulation type (Standard 14 inch minimum size and 6 fish bag limits, Raised Length, Lowered Bag, Raised Length/Lowered Bag, and Slot) and compared catch rates of young-of-year and adults (greater than 14 inches). Standard regulation lakes had good populations of largemouth bass with the second highest PSD. Larger length limits increased the number of large fish, while lakes with lowered bag limits had decreased numbers of larger fish and low PSDs. In future segments, we will combine FAS, INHS and creel data to further evaluate regulations and how they affect angler catch rates. These data can then be used to guide future discussions about various management experiments that might be implemented.

Job 101.1 Evaluating marking techniques for fingerling largemouth bass

OBJECTIVE: To determine the most reliable and cost-effective method for mass-marking fingerling largemouth bass.

RECOMMENDATIONS: No activity in this segment. Final recommendations were presented in previous reports.

Job 101.2. Evaluating various production and stocking strategies for largemouth bass.

OBJECTIVE: To compare size specific survival and growth among different sizes of stocked largemouth bass fingerlings and to compare various rearing techniques.

INTRODUCTION:

Supplemental stocking of largemouth bass *Micropterus salmoides* is a commonly used management tool to enhance populations. Supplemental stocking efforts are directed at either increasing harvest rates and reproductive potential, or restoring predator/prey balance in a fish community. However, for these positive benefits to occur, stocked fish must contribute to the natural population. Numerous studies have examined either the introductions of different genetic stocks of largemouth bass (Rieger and Summerfelt 1978; Maceina et al. 1988; Mitchell et al. 1991; Gilliland 1992; Terre et al. 1993) or the introductions of largemouth bass into ponds (Dillard and Novinger 1975; Modde 1980; Stone and Modde 1982). Surprisingly, few studies have examined the factors thought to influence supplemental stocking of largemouth bass. The few studies that have examined the contribution of stocked largemouth bass to a natural population, examined only one (Lawson and Davies 1979; Buynak and Mitchell 1999) or two lakes (Boxrucker 1986; Ryan et al. 1996). Given that lakes are highly variable, examining stocking evaluations from only one or two lakes limits our ability to make generalizations.

Factors influencing stocking success may include predation, prey availability, and abiotic variables (Wahl et al. 1995). Predation from older age classes of largemouth bass may be especially important given that they have been shown to prey heavily on other species of stocked fish (Wahl and Stein 1989; Santucci and Wahl 1993) and are highly cannibalistic (Post et al. 1998). The availability of appropriate sized prey has also been shown to be important to survival of stocked fish for other species (Fielder 1992; Stahl and Stein 1993). Finally, abiotic factors such as water temperature at time of stocking may contribute to stocking success. High water temperatures at time of stocking may increase stocking stress and subsequent mortality (Clapp et al. 1997). Determining which of these factors is most important to stocking success has important implications for deciding the appropriate locations and times to stock.

Previous stocking evaluations conducted in the Midwest have often examined species that do not naturally reproduce in the recipient water body (e.g. muskellunge *Esox masquinongy*, Szendrey and Wahl 1996; walleye *Stizostedion vitreum*, Santucci and Wahl 1993). Largemouth bass, however, reproduce naturally in most Midwestern impoundments, and therefore supplemental stocking programs are directed at enhancing existing populations. The number of natural fish produced during the year of stocking may influence stocking success through competitive interactions for food and habitat. Because native largemouth bass may out compete stocked largemouth bass, a large natural year class may decrease stocking success in an individual lake. Conversely, stocked largemouth bass may do well in years where the population exhibits high natural recruitment because they are potentially influenced by the same variables. In previous segments, we evaluated success of three sizes of stocked largemouth bass. We found low survival of all size classes. Small fingerlings (2 inch) experienced high levels of predation and stocking mortality and had no long term survival. Medium (4 inch), large (6 inch), and advanced (8 inch) fingerlings had some initial size differences, but there was no long term difference in abundance or growth. Four inch fingerlings were the cheapest to produce and survived as well as other stocking sizes and were the recommended stocking size for producing hatchery largemouth bass. Because of the low overall survival of stocked largemouth bass in these earlier segments, we continue to evaluate stocking success and determine if using alternative rearing and stocking methods will increase survival.

Differences in rearing and stocking method (e.g., intensive raceway versus extensive ponds and point versus dispersed stocking) of the largemouth bass fingerlings may also influence growth and survival. Largemouth bass raised on commercial food pellets have been shown to grow better when stocked into rearing ponds than those fed a diet of fathead minnows (Hearn 1977). A number of Illinois reservoirs and impoundments are stocked with largemouth bass raised extensively in rearing ponds. These and other lakes can also be stocked using largemouth bass raised at state hatcheries. The relative merits of these two rearing techniques have not yet been assessed. In addition, stocking fish into habitat may be preferred to the common practice of point stocking at the boat ramp. Bass have shown increased ability to avoid predation when stocked in a variety of habitats or habituated before stocking (Schlechte et al. 2005). However, these two stocking strategies have not been directly compared in a field setting.

Fisheries managers are often interested in the potential impacts of stocked predators on prey species due to potential "biomanipulation" effects such as changes in density dependent interactions, water clarity or macrophyte abundance (Shapiro et al 1975, Drenner et al. 2002). Case studies addressing community effects of largemouth bass stocking have shown a strong impact on prey populations when introduced into predator free systems and these effects in some cases cascaded to other parts of the aquatic community (Drenner et al. 2002). While some studies have documented strong effects of largemouth bass introductions, propagation of predatory effects through food webs has been shown to be weaker in systems with a history of resident predator populations (Rosenfeld 2000), large bodied prey species capable of reaching size refuges from predation (Hambright et al. 1994; Nowlin et al. 2006), in systems containing keystone species (Stein et al. 1995) and systems with high phosphorous loading rates (Benndorf 1990). Compared to northern oligotrophic systems where strong effects of introduced predators have been documented, lake ecosystems in the lower Midwestern United States possess many of the above characteristics known to limit the propagation of predator effects to other parts of the aquatic community. Therefore there exists considerable uncertainty surrounding the potential responses of lower midwestern lake ecosystems to predator enhancement measures.

Supplemental largemouth bass stocking commonly used by the Illinois DNR represents a unique opportunity to test the applicability of food web theories developed on northern systems to lower Midwestern lake ecosystems and to examine the potential for supplemental largemouth bass stocking as a tool in water quality enhancement. In this segment we present the results of a controlled whole-lake "management experiment" in which 13 Illinois lakes were monitored for a number of community wide parameters over an 8-year period (1998-2005) to examine the effects of supplemental largemouth bass introductions on recipient lake ecosystems. In addition we sought to compare and contrast the responses of lakes with and without gizzard shad (*Dorosoma Cepedianum*) because previous research has speculated that this species may negate the effects of predator enhancement measures (see Stein et al. 1995). Our objectives were therefore to evaluate the potential of predator manipulations to affect the food webs of eutrophic impoundments common in the lower Midwestern United States and to compare the responses of lakes dominated by two common, deep-bodied, planktivore species, bluegill sunfish *Lepomis machrochirus* and gizzard shad *Dorosoma Cepedianum*.

PROCEDURES:

Rearing Technique: Intensive v. Extensive

The effects of rearing techniques on growth and survival of stocked largemouth bass were evaluated in lakes Shelbyville, Jacksonville and Walton Park. Extensively reared bass were produced at the Little Grassy Fish Hatchery where they were held in ponds and fed on minnows until stocking. Walton Park was stocked directly from Little Grassy Fish Hatchery in early August. Jacksonville and Shelbyville utilized lake side rearing ponds. Fish were delivered to the rearing pond in June along with minnows for prey and were allowed to grow until fall. The rearing ponds were drained in late August and fish were marked using fin clips and stocked into the main lake. Intensively reared bass were produced at the Jake Wolf Fish Hatchery where they were held in 265 L concrete tanks and fed commercially produced pellets until stocking. Each fish was given a distinct pelvic fin clip for future identification of rearing technique. Fish were transported from the hatchery in oxygenated hauling tanks to the recipient lakes. Hauling time ranged between 0.5 to 3 hours. Fifty largemouth bass were measured (nearest mm) and weighed (nearest g) before stocking on each date. Fish were released near shore at a single location at each lake. Attempts were made to stock largemouth bass at a rate of 60 fish per hectare, however rates varied by individual lake due to varying success of rearing ponds and hatchery production.

In previous segments, we concluded sampling for fish stocked as part of this study. The last stocking occurred in 2004 and we have monitored these fish until they are no longer found in electrofishing samples. Growth and survival of stocked largemouth bass was determined in each fall and spring by sampling during the day with a 3-phase AC electrofishing boat. Three shoreline transects on each lake were electrofished for 0.5 h each on a sampling date and all largemouth bass were collected, measured, weighed, and examined for clips. Scales were removed from all clipped fish and aged by two independent readers. The stocking year and rearing type was determined for each fish using the age of the fish and the existing clip. Catch per unit of effort (CPUE) was calculated as the number of stocked fish collected per hour and was used as a relative measure of survival across lakes. Growth was estimated using the mean size of bass for each age class at the time of sampling. In this segment we conducted a cost analysis of the different stocking methods. Hatchery costs of producing fish were provided by the hatchery and included the feed cost per fish as well as the estimated hatchery labor and operation cost. The cost of operating the lake side rearing facilities were determined as the price of electricity used to pump the ponds, fertilizer costs and minnow costs. Data was available for cost per fish produced from the rearing pond on Lake Shelbyville, but the cost for the pond were not available for Lake Jacksonville. Cost of rearing for Jacksonville was estimated using the mean cost per fish produced from Shelbyville. Cost per fish was then used to estimate the mean total cost of producing fish per acre for each lake.

Stocking Technique: Boat Ramp v. Dispersed

In this segment, we continued to evaluate the influence of stocking location on survival of stocked largemouth bass. Four lakes were stocked with 100mm largemouth bass fingerlings in 2009 using two stocking techniques. Half of the fish at each lake were stocked at the boat ramp, directly from the hatchery truck, while the other half were loaded into aerated hauling tanks in boats and distributed throughout the lake. Distributed stockings targeted placing fingerlings into wood and vegetated habitat dispersed throughout the lake. Fish were marked with a pelvic fin clip two weeks prior to stocking at the Jake Wolf Memorial Fish hatchery. Fish stocked at the boat ramp were given a right pelvic fin clip and fish to be dispersed were given a left pelvic fin clip. Lakes were sampled two times in the fall and two times in the spring using DC electrofishing. Three 30 minute electrofishing transects were performed on each sampling date and all largemouth bass were collected, measured for total length, examined for clips, and scales were collected from all clipped fish for age determination. CPUE was calculated for stocked and wild fish and contribution of stocked fish to the total bass population was calculated. We then use these data to compare survival and growth of stocked fish from the two stocking techniques.

Influence of Stocked Fish on Resident Populations

To investigate the effects of supplemental largemouth bass stocking in lower midwestern lakes we sampled 13 Illinois water-bodies over an 8-year period from 1998 – 2005. Lakes were grouped into those with (n = 7) and without (n = 6) gizzard shad and a subset of these were then selected to serve as reference systems (Table 2-3). Beginning in the fall of 1999 and each year thereafter, treatment lakes were stocked with juvenile largemouth bass at a target size of 100 mm and target density of 60 fish per hectare (0.70 kg / ha). Fish were given pelvic fin clips (alternating by year) to allow for future identification and to assist in ageing. Each spring (April-May) following stocking (2000-2005) the relative contribution of stocked fish to each year class was indexed in each lake via three-phase AC boat mounted electrofishing on a minimum of two dates. Three fixed one-half hour transects were sampled in each lake on each date. All largemouth bass were netted and measured for total length. Scales were collected from all fin clipped individuals to assist in assigning age classes to stocked fish. To assign ages to wild fish, largemouth bass length frequencies were analyzed using RMIX an “R”-based version of the “MIX” software (MacDonald and Pitcher 1979; MacDonald and Green 1988). Each sample was assumed to contain 3 distinct cohorts, as it was not possible to visibly distinguish among cohorts beyond this age. All fish were therefore assigned into one of three age classes: age-1, age-2 and age-3+. From this data we calculated the proportional contribution of stocked fish to each age grouping for each lake and year (2000-2005).

Data collection was as described in the previous section “Mechanisms Influencing Stocking Success” and previous reports (see Diana et al. 2009) and are not described here. Collected data included benthic macroinvertebrate abundance, relative abundance of prey fish species, zooplankton density and size structure, chlorophyll a, water clarity, and total phosphorous concentration. Time series (annual seasonal means) were analyzed in a replicated before-after control-impact (MBACI) design suited to a repeated measures analysis of variance (Underwood 1994, Kough and Mapstone 1995). This analysis was conducted by fitting a linear mixed model with main factors of treatment (Trt; stocked or unstocked), and before-after (Period), with lakes (L) nested in Trt and years (Y) nested in Period followed by interactions. The three nested terms were considered random (because lakes were considered a random effect in the model) and the remaining terms were considered fixed. The Trt*Period interaction measures any change associated with the onset of the largemouth bass stocking.

FINDINGS:

Rearing Techniques: Intensive v. Extensive

We have concluded electrofishing sampling in the three stocked reservoirs, and can now conduct final analyses. Catch rates and mean size were calculated for each year class and compared between the two rearing techniques. CPUE from electrofishing was calculated and differences between stockings were examined using repeated measures ANOVA and Tukey-Kramer (T-K) adjusted P value were used to determine significance in post hoc tests.

Significant differences existed between success of stocking strategies through time. There was also a significant interaction between stocking strategy and time after stocking (RMANOVA, $F = 2.21$, $P = 0.007$). Extensively reared largemouth bass were recaptured at a significantly higher rate than intensively reared fish the first fall following stocking (Figure 2-1, T-K, $t = 4.11$, adj. $P = 0.02$) and the following spring (T-K, $t = 4.33$, adj. $P = 0.007$). After the first spring, catch rates for both intensive and extensive fish declined to below 1 fish per hour of electrofishing and there was no longer a significant difference between the two rearing strategies (adj. $P > 0.05$). Despite better survival of extensively reared fish, we saw low long term survival of stocked fish from either rearing strategy and no long-term differences in relative abundance.

Significant differences also existed in mean size among intensive, extensive, and wild fish. Again there was a significant interaction between stocking strategy and time following stocking (RMANOVA, $F = 8.97$, $P < 0.0001$). Extensively reared fish were larger than wild fish (T-K, $t = 4.18$, adj. $P = 0.02$) but not significantly larger than intensively reared fish (T-K, $t = 3.06$, adj. $P = 0.50$) the first fall following stocking (Figure 2-2). Wild and intensively reared fish were also not different in size in the first fall following stocking ($t = 0.58$, adj. $P = 1.00$). Differences in size were no longer significant in the spring following stocking. Extensively reared fish were similar in size to both wild (T-K, t = 2.64, adj. P = 0.82) and intensive fish (T-K, t = 0.38, adj. P = 1.00) and no difference existed between intensive and wild fish (T-K, t = 1.60, adj. P = 1.00). Wild, intensive and extensive fish remained similar in size throughout the remaining months they were collected in electrofishing samples. Extensively reared fish were larger than intensively reared fish and wild fish when they were stocked and they remain larger through the first fall. However this size differences is short lived and by the following spring there are no differences in size among these fish.

The cost of producing fish varied among rearing types and individual lakes. Lake Shelbyville was less costly to stock due to its large size, fish were stocked at a lower density. For all lakes, mean total cost of stocking was higher for extensively reared fish (Table 2-1) as a result of the greater cost per fish produced.

Stocking Techniques: Boat Ramp v. Dispersed

Four lakes were stocked with four inch largemouth bass in 2009. All lakes continued to have very low survival of both boat ramp and dispersed stocked fish to the first fall following stocking (Table 2-1). No fish stocked in 2009 were observed in the spring of 2010. We have begun to find some fish from previous stockings in our electrofishing samples, but the CPUE is very low and there is no consistent difference between stocking method. We will need to age these fish in order to determine which year they were stocked. The poor survival of all stocked fish may be due to the warm lake temperatures on the date of stocking. High mortality of dispersed fish could be affected by the increased handling time associated with loading the fish onto a boat and dispersing them throughout the lake. We did not however observe greater survival of fish stocked at the boat ramp where this handling did not occur. Additional years of stocking are required to evaluate differences in these stocking techniques. We will continue to stock four lakes each year using these strategies in order to make management recommendations regarding stocking locations to maximize survival.

Influence of Stocked Fish on Resident Populations

Bluegill dominated lakes

In lakes that did not contain gizzard shad, the average annual proportional contribution of stocked largemouth bass ranged from 7-34% of age-1 fish, 4-17% of age-2 fish, and from 1-5% of age-3 and older fish (Figure X). Across years stocked fish made up an average of 19(±5)% of age-1, 10(±4)% of age-2 and 3(±2)% of age-3 and older largemouth bass collected in spring surveys from these gizzard shad free lakes. The repeated measures ANOVA (R-ANOVA) indicated a significant decrease in the density of juvenile and shallow bodied littoral prey fish collected in fall seine samples from lakes which did not contain gizzard shad in response to largemouth bass stocking. Average density of littoral prey fish in standardized fall seine samples decreased from 4.51 fish per square meter to less than one fish per square meter while the number of fish in seine hauls increased slightly in control systems over the same period. The change in littoral prey fish represented an 86% decline in density relative to controls after largemouth bass stocking (Table 2-4). In contrast, our analysis indicated no significant change in the relative abundance of adult prey fish collected via shoreline electrofishing relative to controls in response to largemouth bass stocking. Furthermore, the majority of invertebrate and all of the water quality parameters examined showed no significant changes after initiation of largemouth bass stocking (Figure 2-4). A noteworthy exception was a significant increase in total littoral benthic macroinvertebrates in lakes receiving largemouth bass stockings where total macroinvertebrate density increased from an average of 4,307/m^2 to over 8,500/m^2. During the same period total benthic macroinvertebrate density in control systems decreased from 7,000 to 3,600 /m^2. Patterns for the two most abundant individual groups followed a similar trend of increase after largemouth bass introduction however these patterns were smaller and more variable and our analysis indicated only marginally significant changes for average density of Choronomidae and no change in Ceratopogonidae (Table 2-4).

Gizzard shad dominated lakes

In lakes containing gizzard shad the average annual proportional contribution of stocked largemouth bass ranged from 13-40% of age-1 fish, 8-33% of age-2 fish, and 1-18% of age-3 and older fish (Figure 2-3). Across years stocked fish comprised an average of 31(±5)% of age-1, 23(±5)% of age-2, and 10(±3)% of age-3 and older largemouth bass collected in spring surveys from lakes containing gizzard shad. Unlike the bluegill dominated lakes, there was no significant change in average littoral prey fish density in seine samples from the lakes containing gizzard shad (Table 2-4). Similar to lakes without gizzard shad, there was no effect of largemouth bass stocking on the relative abundance of adult fish collected during standardized electrofishing surveys. The lack of significant effects on fish communities also was mirrored in invertebrate and water quality metrics where there were virtually no changes in response to largemouth bass stocking (Table 2-4). Our analysis for individual groups of benthic macroinvertebrates indicated a significant effect on Chironomidae density however after examining the time series this effect was due to an increase in the control lakes that was not present in the stocked lakes.

RECOMMENDATIONS:

Comparisons between intensive and extensive stocked fish showed differences in growth and survival initially following stocking. Extensively reared largemouth bass had higher survival than intensively reared fish and were larger than wild fish in the fall following stocking. They remained more abundant than intensively reared fish the following spring, but were no longer larger than wild fish. Despite higher initial stocking success with extensively reared fish, there were no differences in growth or survival by the second fall following stocking and survival was low for both stocking strategies (< 1 fish per hour of electrofishing). Raising fish in a rearing pond greatly increases the cost of production, however when fish are harvested from the pond, they are larger than the intensively produced fish. In addition the greater survival of extensively reared fish until the second fall following stocking suggests there is potential for extensive rearing to produce more harvestable fish, however long term mortality was high and there was no difference in abundance after the second fall. There may be other benefits to using lakeside rearing ponds for producing fish due to the rearing occurring in a more natural environment and allowing the fish to feed on natural prey before stocking rather than artificial feed. Due to the close proximity to the stocking lake, these fish should experience a similar climate and temperature regime to their destination lake and may reduce the acclimation time required when released in the lake. Experience with feeding on fish prior to stocking has been shown to result in greater growth and survival following stocking for other species (Suboski and Templeton 1989; Szendrey and Wahl 1995; Wahl et al. 1995b) as well as in laboratory experiments in this project (see previous reports). However, low survival of all stocked largemouth bass led to few fish growing large enough to contribute to the fishery. Fish did not reach 14 inches until their fourth year in the lake. At this time CPUE for these fish was less than 0.5 per hour of electrofishing and did not significantly contribute to the adult largemouth bass population.

We will continue studies evaluating stocking location to assess the potential to increase survival of stocked largemouth bass. In the first three years, we have observed very low survival of largemouth bass stocked both at the boat ramp and dispersed throughout the lake. Survival of these fish has been lower than survival observed from previous stockings we have evaluated. Survival may have been limited due to the high temperatures on the dates of stocking or the increased handling time due to the stocking techniques. Future efforts will be made to stock the fish during the lowest possible temperatures and fish will be handled with care to facilitate survival. We will continue to compare survival of point stocking versus dispersed stocking at multiple locations of optimal habitat throughout the study lakes. In 2010 we will stock Lake Charleston, Homer Lake, Lake Mingo, and Otter Lake using these two methods. We will evaluate growth and survival by conducting spring and fall electrofishing. Ultimately we hope to evaluate if increased survival of stocked largemouth bass can be achieved through these techniques and provide management recommendations on best stocking method.

Our results continue to suggest the need to evaluate long-term survival of largemouth bass to fully evaluate stocking success. Although stocked fish may exhibit similar survival to wild fish in a lake initially following stocking, significant mortality can occur through the adult age. Stocking success could be evaluated incorrectly if long-term survival is not considered. We have found that recruitment of largemouth bass is not determined in the first year after stocking. Many previous evaluations of stocking success for other species have not examined stocking success beyond the first spring. These studies may omit a critical period for determining survival of stocked fish. For largemouth bass, success of stocked fish in the first year is often not reflected in creel data providing further evidence for variable survival following the first year after stocking (Boxrucker 1986; Neal et al. 2002). Managers should consider survival to age-1 and adult fish when managing a lake or reservoir by stocking. Considering the availability of appropriate prey and habitat for larger stocked fish may reduce mortality and increase recruitment to the fishery. We continue to evaluate different stocking methods which may increase long term survival of stocked largemouth bass. At this point, we have not been able to find benefits of stocking extensively reared fish or larger fish. Future efforts will be required to assess if stocking fish into optimal habitat can increase stocking success. In future segments we will examine other lake specific factors that may influence stocking success such as prey abundance and availability, available habitat, thermal regimes, and fishing pressure. We will examine variation among lakes in order to further explore what factors may play a role in determining growth and survival of stocked fish.

In lakes where gizzard shad were absent we found that increased piscivory from stocked fish significantly reduced small bodied and juvenile fish density. There was little effect on adult populations of prey fish that were comprised mostly of bluegill. Hambright et al. (1986) found a similar effect of piscivory in a pond study where the presence of largemouth bass increased the size distribution of bluegill but caused only a slight (15%) decrease in bluegill biomass compared to piscivore free ponds. This pattern in response to largemouth bass predation is consistent with other studies focused on the effects of gape-limited piscivores foraging on deep-bodied prey species (Tonn et al. 1992; Hambright et al. 1994; Findlay et al. 2000). Combined these results suggest that stocked largemouth bass are capable of affecting the size structure of bluegill populations however they do not significantly reduce the abundance of invulnerable adult bluegill. As a result they do not influence the effects of adult bluegill populations on lower trophic levels. Bluegills are known to outgrow the gape limitation of largemouth bass (Lawrence 1957; Werner et al. 1988) and are commonly abundant in systems containing largemouth bass throughout the Midwestern and southern United States. Due to their ability to outgrow the gape limitation of predators and associated behavioral and physical anti-predator adaptations (Howick and O'Brien 1983) bluegill sunfish appear to limit the effectiveness of biomanipulation via predator enhancement in these systems.

The lack of fish community responses to piscivore enhancement in lakes dominated by gizzard shad suggests that this species may also not be subject to consumer control by largemouth bass. Stein et al. (1995) argued that gizzard shad populations are not subject to consumer control by predators due to their high fecundity (Parrish and Vondracek 1989) and their ability to quickly outgrow the gape of predators (Hambright et al. 1991). This hypothesis has been supported by several studies utilizing bioenergetics-based assessments of gizzard shad consumption by resident and introduced predator populations in midwestern impoundments (Carline et al. 1984; Johnson et al. 1988; Dettmers et al. 1998). For example Johnson (1988) found that introduced predators including percids and esocids (stocked at similar rates and sizes to the largemouth bass in our study) combined with resident largemouth bass predation could only consume about 20% of the total annual production of age-0 gizzard shad in an Ohio impoundment. In another bioenergetic simulation study, Carline et al. (1984) showed that even an extremely dense largemouth bass population (33.4 kg/ha) would be unlikely to consume total annual production of an average gizzard shad population (even under the unrealistic assumption that fish were vulnerable at all sizes). Our results combined with those of past researchers suggest that gizzard shad populations are not subject to consumer control by piscivores and therefore may limit the effectiveness of biomanipulation via predator enhancement where present.

Patterns of cascading effects in lakes where gizzard shad were absent further highlight the possible importance of size structured interactions in these systems. Observed increases in littoral benthic invertebrate density in our study and a lack of change in zooplankton communities are consistent with previous studies on foraging behavior of bluegill (the dominant planktivore/benthivore in these systems). Bluegills are known to undertake ontogenetic habitat shifts during their life history in response to predation risk where juveniles primarily occupy shallow littoral areas until reaching body depths that reduce their vulnerability to gape limited predators (Werner et al. 1983; Paukert and Willis 2002). Concurrent with this habitat switch is a shift in diet from littoral benthic invertebrates to pelagic zooplankton (Werner et al. 1988). These patterns in bluegill foraging may explain our observed cascading effects on littoral benthic invertebrates and lack of effects on zooplankton as we documented declines in the density of littoral and small-bodied fish but not adult populations known to prey heavily on zooplankton. Bluegill are known to structure invertebrate communities through predation (Hambright et al. 1986) and several previous studies from both North America and Europe have documented taxonomic increases in benthic invertebrate communities following reductions in the density of bluegill (Pierce and Hinrichs 1997) and other benthivorous fish (Svensson et al. 1999; Leppa et al 2003; Potthoff et al. 2008). Our results suggest that littoral benthic invertebrate populations in midwestern impoundments are subject to control by mid-level fish consumers and the strength of these effects may be influenced by piscivore abundance.

An emerging body of literature suggests that the effects of piscivores on lower trophic levels in aquatic food webs are tightly linked to the vulnerability of prey fish species within the system in question (Hambright et al. 1994; Drenner and Hambright 2002; Nowlin et al. 2006;) and this pattern has continued in recent studies (Pothoff et al. 2008; this study). The inability of gape-limited piscivores to control some species of planktivorous and benthivorous fish has been demonstrated in previous smaller scale studies and now extended to the whole-lake scale in experiments conducted in both Europe (Mehner 2010) and North America (this study). Because adults of such species are not subject to direct mortality by piscivore predation they may continue to suppress large bodied crustacean zooplankton through direct predation, continued production of fish larvae, or indirect effects on phytoplankton communities (Hansson et al. 1998). While our results demonstrate a degree of resilience in the aquatic communities of Illinois lakes to predator effects we caution that managers should not ignore the potential impacts of supplemental largemouth bass stockings on prey fish communities. Littoral prey fish populations are a primary driver of largemouth bass recruitment in many Illinois lakes (Parkos et al. *in press*). Our results suggest that an unintended consequence of supplemental largemouth bass stocking may be increased intraspecific competition for limited prey resources. Evidence suggests that littoral prey fish are a limited resource in Illinois lakes and their abundance should be a primary consideration when making decisions regarding supplemental stocking of largemouth bass populations.

Job 101.3 Assessing the long-term contribution of stocked fish to largemouth bass populations.

OBJECTIVE: To evaluate the long-term contribution of stocked largemouth bass to the numbers of reproducing and harvestable adults.

INTRODUCTION:

Fish stocking is common throughout North America for a number of species. Fish may be stocked to introduce a species to a new system (Douwalter and Jackson 2005), sustain a population in areas where the fish do not reproduce naturally (Santucci et al. 1994), supplement wild populations that have been reduced due to anthropogenic influences (i.e. fishing, habitat degradation; Wingate 1986) or to alter the genetics of a population (Maceina et al. 1988, Buckmeier et al. 2003). The initial success of a stocking program depends on the survival of introduced fish. Much research examining the success of stocking programs has focused on initial survival (Boxrucker 1986, Buckmeier and Betsill 2002, Hoffman and Bettoli 2005), though more recent work has focused on survival to adulthood (Diana and Wahl 2008, Buynak and Mitchell 1999, Wahl and Stein 1993).

Despite high initial survival, stocked fish often represent only a small proportion of the population as adults (Diana and Wahl 2008, Buynak and Mitchell 1999). The reasons for the poor survival between introduction and adulthood often remain unclear, but does suggest that stocked fish are less equipped for long-term survival than wild fish (Buynak and Mitchell 1999). If the longterm goal of stocking includes increasing the population of the stocked species, success depends not just on survival to adulthood, but also on long-term reproductive abilities (Currens and Busack 1995, Waples and Do 1994). However, understanding how stocked fish contribute to the reproductive output of the populations into which they are stocked has received little attention.

If poor survival of stocked fish is tied to their ability to obtain resources or exploit preferred habitats (Donovan et al. 1997, Szendrey and Wahl 1996), then those fish that do survive to adulthood may exhibit poorer reproductive output compared to their wild counterparts. Furthermore, hatchery rearing conditions (high density, disease treatments, water quality issues), may also affect the development of reproductive organs (Huntingford 2004) or modify the behavior of fish in such a way that it could affect reproductive ability of adults (Berejikian et al 1997, Jonsson and Jonsson 2006). For example, stocked Atlantic salmon females have been found to deposit fewer eggs, display fewer courtship behaviors, spend less time breeding, and have lower survival of eggs than wild fish (Jonsson 1997). Likewise, stocked male Atlantic salmon have lower success at mate acquisition than their wild counterparts (Jonsson 1997). As stocked fish become part of the adult population, it is important to understand the reproductive abilities of these fish in order to determine how stocking affects long-term population dynamics.

Largemouth bass are stocked regularly into lakes and reservoirs throughout their range and are often used to supplement naturally reproducing populations (Boxrucker 1986, Maceina et al. 1988, Buynak et al. 1999). Previous work examining success of stocked fish to adulthood have found that survival is often lower than wild fish (Diana and Wahl 2008, Buynak and Mitchell 1999). Although it is assumed that increases in the standing stock of populations are the direct result of stocking efforts, little data exist to either refute or support that idea for largemouth bass. If the stocking does indeed increase the standing stock of adult largemouth bass, it also remains unclear how those increases effect reproduction and recruitment in subsequent generations.

Largemouth bass likely home to natal areas to spawn (Ridgway et al. 1991, Waters and Noble 2004), and it is possible that introduced fish may not compete successfully with resident fish for optimal spawning sites or may simply make poor choices in selecting nesting sites. Under either of these scenarios, the level of reproductive success of stocked bass would be lower than that of resident bass. To justify continued stocking efforts for largemouth bass in Illinois, it is important to determine the actual contribution that stocked fish make to bass populations. The objective of this job is to compare the survival and reproductive success of stocked bass to resident populations. In this way, we can assess the costs and benefits of the bass stocking program in a long-term timeframe.

PROCEDURES:

Largemouth bass to be stocked in each selected study lake were those produced at the Little Grassy Hatchery bred specifically to be fixed for the MDH-B2B2 genotype as a genetic tag and were stocked into target lakes. Prior to stocking, a sample of naturally produced largemouth bass were collected from each study lake and analyzed to determine the inherent background frequency of the MDH-B2 locus. Six study lakes were stocked and sampled; Lake Shelbyville and Forbes Lake beginning in 1998, and Walton Park, Murphysboro, McLeansboro, Sam Parr in 1999. Samples of fish from the hatchery rearing ponds were sampled, and protein electrophoretic analysis (Philipp et al., 1979) was used to confirm that these fish had the MDH B2B2 genotype. Stocking continued in all lakes through 2005. Preliminary sampling of largemouth bass began in 2002 and continued through 2010. Clips on fish were noted to determine the survival of stocked fish from initial stocking through reproductive ages. One hundred YOY largemouth bass per lake were collected starting in 2002, when the earliest stocked fish should have begun reaching maturity. Young-of-year from the six lakes were sampled by boat electrofishing in each year to determine if the frequency of the MDH B2 allele had increased through reproduction of the stocked fish. These sampling efforts were used to document the contribution of stocked fish to the reproductive population.

To determine if stocked fish survived to adulthood in these lakes we ran an analysis of variance on the proportion of stocked fish in the population immediately after stocking versus the average proportion of stocked fish in the population in the years following the stocking. Correlation analysis was used to determine if measured variables were important in influencing the change in MDH B2 allele frequency across years in the study lakes. McCleansboro Lake was excluded from the analysis due to high initial MDH B2 allele frequencies that made detection of changes in the frequency difficult. Among the factors examined were proportion of B2B2 adults in the population and lake size (see Job 101.4 for electrofishing sampling methodology).

Finally, to determine if B2B2 adults were contributing to reproduction in proportion to their presence in the population, observed MDH B2 allele frequency was regressed against predicted frequency. To estimate the predicted MDH B2 allele frequency of naturally spawned young-of-year from adult fish, we calculated the total frequency of the MDH B2 allele in the adult population. The proportion of natural adult largemouth bass was multiplied by the background MDH B2 allele frequency for those fish and was added to the proportion of B2B2 adults in the population. If stocked fish are contributing to reproduction equal to their proportion in the population, the slope of the regression of actual and predicted MDH B2 allele frequencies in young-of-year fish should equal 1. Deviations from 1 indicate either lower or greater contribution than expected.

FINDINGS:

The original largemouth bass fingerlings stocked into each lake were analyzed to determine if the fingerlings all had the MDH B2B2 genotype. All samples analyzed from each stocking were 100% MDH B2B2 genotype with the exception of fingerlings stocked into Lake Shelbyville in the summer of 2001. In that case, five of the fifty fingerlings that were analyzed had the MDH B1B2; therefore a correction factor was used to analyze samples from Lake Shelbyville. The background frequencies of largemouth bass from four of the six study lakes had less than 20% of the individuals with the MDH B2B2 genotype. The exceptions were Forbes (33%) and McLeansboro (55%) (Table 3-1). The higher frequency of the MDH B2 allele from McLeansboro is problematic and this lake was eliminated from assessments of the contribution of stocked fish to recruitment.

Initial stocking of young-of-year largemouth bass found that stocked fish initially represented from 10-40% of the total population of largemouth bass in the lakes we examined (Figure 3-1). As adults, stocked fish represented from 5-35% of the total adult largemouth bass population (Figure 3-1). The proportional representation did not change from initial stocking through maturity in any of the lakes examined in this study (no $P<0.14$). The lakes showed a great deal of variation between lakes in the change in the MDH-B2 allele frequencies, but generally showed an increase (Figure 3-2). One of the study lakes, Walton Park, showed a major change (164% increase) in the frequency of the MDH B2 allele due to the stocking of hatchery fingerlings. Sam Parr Lake (99% increase) and Lake Murphysboro (76% increase) showed a moderate change in allele frequencies whereas Forbes Lake (14% increase) and Lake Shelbyville (17% increase) showed only minor influence of stocked fish contributing to the reproducing population (Table 3-2).

Correlation analysis found that the proportion of the adult largemouth bass that were from stocked fish was strongly related to the frequency of the MDH B2 allele for that year class of YOY (Pearson $r = 0.65$, $P = 0.0006$, Figure 3-3). As proportion of B2B2 adults in the population increased so did the frequency in the B2 allele in that year class of YOY. Thus it appears that stocked largemouth bass do contribute to reproduction when they reach reproductive sizes. In addition, lake size showed a significant negative relationship with the change in the frequency of the MDH B2 allele (Pearson $r = 0.91$, $P = 0.03$, Table 3-2).

Stocked B2B2 adult largemouth bass appear to reproduce as effectively as natural largemouth bass if they survive to maturity. The slope of the regression of predicted vs.

actual MDH B2 allele frequency based on the proportion of B2B2 adults was 0.72 and was not significantly different from 1 ($F_{1,28}$=3.54, P=0.07; Figure 3-4). Therefore, it appears that the most important factor affecting the contribution of stocked fish to a population is the number of individuals surviving to become reproductive adults.

RECOMMENDATIONS:

Stocked fish contributed to the spawning population in some of the study lakes. Genetic frequencies from YOY spawned from largemouth bass stocked with the MDH B2 allele increased very little in two of the study lakes (Forbes Lake and Lake Shelbyville). Forbes Lake and Lake Shelbyville are much larger than the other lakes, which may influence the effectiveness of stocking programs in these lakes. Stocked fish appear to have made significant contributions to three of the smaller lakes, Lake Murphysboro, Sam Parr Lake and Walton Park.

While data suggests that lake size may be an important factor influencing the success of a stocking program, other factors may be involved as well. Factors such as prey availability and overall adult largemouth bass density could affect stocked largemouth bass condition and ability to secure good nesting sites differently than wild fish and will be examined in future reports. In addition, other factors that affect the success of stocked bass reproductive contribution may be similar to factors being examined under Job 101.2 that can influence the survival of stocked largemouth bass in different lakes. In particular factors that affect the early survival and proportion of stocked largemouth bass that reach sexual maturity are very important. Once stocked largemouth bass do reach sexual maturity, they appear to make similar contributions to reproduction as natural adult largemouth bass. From our data it appears that stocking largemouth bass will make the greatest contribution in small lakes when natural reproduction by resident largemouth bass is low.

Job 101.4. Evaluating factors that influence largemouth bass recruitment in Illinois.

OBJECTIVE: To determine important mechanisms affecting largemouth bass recruitment in Illinois impoundments and develop recruitment indices for management.

INTRODUCTION:

Recruitment in fish populations is a process driven by growth and mortality during the earliest life stages (Hjort 1914; Houde 1987). Most fish species produce many thousands of offspring in a reproductive season and a large majority of these offspring die before they reach the end of their first year of life. Sometimes this early mortality is episodic, involving large numbers of individuals dying simultaneously, and at other times, high mortality rates occur throughout the first growing season of life (Houde 1989). Even slight differences in mortality rates can result in large variation in year class strength between populations and years. Parkos and Wahl (2002) provided a conceptual model of largemouth bass recruitment that accounted for the importance of parental care to survival of the earliest life stages (embryo and larva) of largemouth bass. Events that can interfere with parental care of developing offspring, such as extreme weather events and removal of nesting males by angling (Kramer and Smith 1962; Philipp et al. 1997), were hypothesized to have the potential to negatively affect overall year class strength. Parkos and Wahl (2002) concluded that for some populations and cohorts, processes operating during the earliest developmental stages of YOY largemouth bass (i.e., survival of embryos and larvae) have a larger effect on overall recruitment strength than patterns of mortality occurring towards the end of the first year of life (i.e., first summer and winter survival of juveniles).

Aquatic vegetation is a habitat feature that influences the abiotic and biotic conditions that determine largemouth bass recruitment strength. Aquatic vegetation is often an important habitat feature for age-0 fishes and recruitment (Wright 1990; McRae and Diana 2005). Aquatic vegetation can benefit fish by decreasing turbidity, providing substrate for spawning, increasing structure for avoiding predators, and acting as habitat for important prey (Savino and Stein 1982; Carpenter and Lodge 1986; Scheffer et al. 1993). Previous examinations of the effects of aquatic vegetation on largemouth bass growth and recruitment have been mixed. Whether or not aquatic vegetation has a positive or negative effect on YOY largemouth bass is likely to be dependent on the level of vegetation coverage. Too much vegetation will negatively influence YOY largemouth bass foraging efficiency and subsequent growth (Anderson 1984; Caliteux et al. 1996; Sammons et al. 2003), while a moderate amount of coverage could positively affect YOY survival (Miranda and Pugh 1997). Any benefits provided will also vary by the type of structure offered by different vegetation species (Havens et al. 2005). In this job, we are evaluating the role of vegetation by relating densities and types with largemouth bass recruitment.

Woody debris may also provide some of the same benefits offered by aquatic vegetation. Studies have shown a potential for higher overwinter survival of young-of-year largemouth bass with increasing available woody brush habitat when predators are present (Miranda and Hubbard 1994). In reservoirs, higher centrarchid abundance was associated with coarse woody habitat (Barwick 2004) and removal of coarse woody habitat has also been shown to cause reduced growth rates in largemouth bass and a shift to eating more terrestrial prey (Sass et al. 2006). Numerous studies have demonstrated that complex wood substrate provides habitat for macroinvertebrates (O'Connor 1991; France 1996; Smokorowski et al. 2006). These available food resources concentrate prey fish and in turn provides forage for largemouth bass increasing their foraging success (Hickey and Kohler 2004). All these previous data suggest that woody habitat provides an integral component of multiple trophic levels in many aquatic ecosystems. We are conducting management experiments where vegetation and woody habitat are manipulated (e.g. plantings and removals, varying density and presence versus absence) to examine changes in largemouth bass growth and survival at the lake scale.

Spatial heterogeneity in physical littoral habitat has been shown to influence many population and community characteristics of fish assemblages within lake ecosystems. Studies focused on largemouth bass have shown littoral habitat to be an important determinant of age-0 fish distribution and these studies generally have found that largemouth bass prefer structurally complex habitats in the form of woody cover, leaf pack, coarse substrates and aquatic vegetation (Annett et al. 1996; Irwin et al. 1997). Laboratory and field studies have shown that complex physical habitat provides a refuge from predation for juvenile fishes while simultaneously increasing prey resources (Savino and Stein 1982; Miranda and Pugh 1997). While previous research has identified influences of habitat variability on population dynamics of largemouth bass (Meals and Miranda 1991) the majority of studies been conducted on spatial scales that incorporate multiple habitat patches which has made it difficult to discern how fish use qualitatively different microhabitats (Summerfelt 1993; Annett et al. 1996). In addition, specific differences in the biotic communities among microhabitats (e.g. macroinvertebrates, zooplankton) within the littoral zone have not received attention. In this segment, we sampled 3 common and distinct shoreline microhabitats including vegetated shorelines, shorelines with laydown coarse woody debris, and bare shorelines across two Illinois lakes to examine microhabitat associations of fish communities and invertebrates. This work is intended to identify the degree to which fish and invertebrate communities can be distinguished based on microhabitat associations and also will aid in the identification of patterns in abundance of food web components that may be important to age-0 largemouth bass.

Another potential factor influencing largemouth bass recruitment is dam escapement. Escapement from reservoirs generally increases by four times in the spring and summer when water levels are high (Paller et al. 2006). The increase in escapement coincides with the time when largemouth bass are reproducing and may impact recruitment. In addition, this potential influence might be greater on smaller lakes where fish have a higher probability of being in close proximity to the discharge over the dam. Therefore, it may be possible to develop an index of watershed to lake acreage that could be used to predict potential lakes where escapement could be a concern.

PROCEDURES:

Vegetation Management Experiment

In this segment, we continued a multiple lake experiment to evaluate different vegetation management strategies. We identified 13 lakes and divided them into three treatments based on management objectives. Treatments include management to increase vegetation, management to reduce vegetation, and control treatments where vegetation will not be manipulated. Management to increase vegetation has continued on Dolan Lake and Lake Paradise. Dolan Lake was drawn down in winter of 2006-2007 and treated with rotenone in an attempt to remove carp and gizzard shad and expose the seed bank to promote vegetation growth. Successful reduction or removal of carp coupled with establishing new vegetated areas should increase overall vegetated cover in Dolan Lake.

In this segment, we continued to evaluate a large vegetation planting effort in Lake Paradise through cooperation with Illinois District Biologist Mike Mounce and the City of Mattoon Water Department. Exclosures were constructed in 2008 using varying designs to reduce loss of vegetation from carp and turtles. Exclosures were constructed using varying lengths of PVC coated wire fencing. Fencing was shaped into a cylinder and closed using cable ties. Lengths of rebar were driven into the substrate and attached to the fencing cylinders using heavy duty wire ties to secure the exclosure in place. After attachment to the rebar, the cage was driven into the substrate an additional 50 to 100 mm (depending upon substrate) to seat the exclosure and ensure no fish passage under the fencing. Exclosures were utilized in two plantings in the spring of 2008. The first planting occurred in early June of 2008 and was designed to test the success of three different exclosure types for planting of wild celery and sago pondweed tubers. One replicate included a large exclosure, four small dispersed exclosures and four small clustered exclosures. Large exclosures were constructed of 6.1 m of fencing creating an exclosure with a 2.0 m diameter (area = 3.0 m^2). Small exclosures were constructed from 3.0 m of fencing creating an exclosure with a 1.0 m diameter (area = 0.7 m^2 approximately ¼ the size of large exclosures). Wild celery were planted using small bags of cheese cloth weighted with pea gravel with 5 tubers in each bag. Large exclosures were planted with 26 bags of wild celery and small exclosures with 6.5 bags per exclosure. Sago pondweed tubers were planted in a similar manner with 7 tubers in each bag. Large exclosures were planted with 31 bags of sago pondweed and small exclosures were planted with 8 bags. Ten replicates were planted with wild celery and 9 replicates were planted with sago pondweed.

The second planting occurred in late June of 2008 and was designed to test the success of chara, coontail, and American pondweed. These species were planted three stems in a cluster at 1 foot spacing throughout an exclosure. One replicate consisted of two large exclosures and four small exclosures. Three replicates were planted for each vegetation type. For all treatments, planting location was along low sloping shoreline, with adequate sunlight, and shorelines protected from southern wind in order to promote successful establishment and growth of aquatic vegetation. Exclosures were visited in August of 2008 and June of 2009 to evaluate planting success. Each exclosure was divided into 4 quadrates. Each quadrate was visually assessed for percent cover of planted vegetation. In this segment, we supplemented the initial plantings by adding

American pondweed and wild celery in cages where there was no survival from previous plantings in mid July 2010. American Pondweed was planted in 11 large cages and 20 small dispersed cages and wild celery was planted in 12 large cages and 33 small dispersed or clustered cages. These cages were revisited and scored for vegetation in early August 2009. At this time, cages that were initially planted that had plant survival and were not replanted in 2009 were also revisited and scored for percent cover.

A subsample of exclosures were sampled for fish, macroinvertebrates and biomass of vegetation. Fish were collected using a backpack electrofisher (250 V DC, 6 Amps). A 1 meter circle was electrofished around each exclosure and then the interior of the exclosure was sampled. All fish were identified to species, measured for total length and released. Benthic invertebrates were collected using a modified stovepipe sampler. The benthos was sieved through a 250-μm sieve bucket and preserved in ETOH and rose bengal. Invertebrates were sorted, identified, and measured at the lab. Vegetation was collected if it was sampled in the modified stovepipe sampler. All vegetation was identified to species and weighed. We will monitor the success of the different exclosure designs and vegetation types by assessing vegetation in June and August in future segments.

We have been monitoring two lakes as part of the vegetation removal treatment. Stillwater Lake and Airport Lake have high vegetation densities and are in need of treatment to remove vegetation. Monitoring of pre vegetation management began in previous segments and continued in this segment. Treatment for vegetation began in the spring of 2010. Sonar was applied to Stillwater with the intention of completely removing Eurasian milfoil from the lake as well as other vegetation which has become overabundant. Eurasian milfoil is the dominant vegetation type and is invasive in Illinois. Airport Lake was treated with Reward two times, once in the spring and once in July. Reward is being applied to reduce the vegetation lake wide and was targeted to remove Eurasian milfoil which had begun to establish in the lake. We will monitor changes in largemouth bass populations and prey organisms throughout and following the treatment period. Control lakes will be used to compare changes in largemouth bass populations to lakes where vegetation is being manipulated to determine the effects of vegetation management. Control lakes include 3 levels of vegetation (high, medium, and low) based on percent cover.

In this segment, we continued field sampling of the 13 lakes for pre manipulation and control conditions. Largemouth bass populations, vegetation, prey resources, and fish communities were monitored. Three AC electrofishing transects were sampled two times in the spring and two in the fall at each lake. All fish were identified to species and measured for total length. Largemouth bass were also weighed and scales were taken for age and growth estimation. Benthic invertebrates were sampled two times annually in June and August at six sites using a stovepipe sampler. Zooplankton, larval fish and seine samples were performed bimonthly on 8 lakes and monthly on the remaining 5 lakes. Larval fish were collected using a 0.5 m diameter plankton push net with a 500um mesh and a 1:5 width to length ratio. Larval pushes were sampled for 5 minutes and total water sampled was measured using a torpedo flow meter mounted in the center of the net. Zooplankton was sampled using vertical tows at 4 inshore and 4 offshore locations at each lake using 0.5 m diameter plankton net with 63 um mesh and a 1:3 width to length ratio. All samples were preserved and brought to the laboratory where they were identified and counted. Seine samples were taken at 4 shoreline locations on each lake using a 1.2 x 9.1 m seine with a 1.2 x 1.2 m bag. The width length and depth of each transect were recorded to determine the volume of water seined. All fish collected were identified to species and a minimum of 50 individuals were measured for total length and additional fish were counted.

Lakes were mapped for vegetation in June and August using GPS mapping techniques. In this segment, GPS was used to trace the vegetated edge and waypoints to identify transitions in types and densities of vegetated areas. GPS data was then converted into GIS layers and digitized in ArcGIS 9.1. Once areas of homogenous vegetation were identified, density and mass of each species was measured. Ten rings of 0.5 m diameter were distributed throughout the different vegetated areas. All vegetation in a ring was removed, separated and identified to species and weighed. The mass of each vegetation type in a ring was used as a representative sample for the vegetated area. These rings will be used to estimate densities and biomass of each vegetation type present. Lake area, lake shoreline, vegetated area, and vegetated shoreline were digitized from hand drawn maps using ImagePro Plus ver. 4.5.1 software. GIS tools were then used to calculate vegetated area and vegetated perimeter of the lake. Vegetation rings were used to assign densities and mass of each vegetation type to polygons of homogenous vegetation.

Vegetation and Woody Habitat Enclosures

In this segment we continue to examine patterns in abundance of young-of-year largemouth bass, other fish species, and associated biotic communities among three common lakeshore habitat types in two Illinois lakes. During August 2009 three replicate vegetated, wooded and open shoreline sites were randomly selected in Lincoln Trail Lake and Lake Paradise. At each site, a block net (100 X 3.04 m) was used to enclose an area of shoreline (mean area ± SE = 45.5 ± 4.3 m^2) during sampling. Within vegetated sites three 0.5 m diameter circular quadrats were sampled for species identity, stem density and standing biomass of macrophytes. Benthic macroinvertebrates were sampled from littoral sediments using a modified stovepipe sampler as described in previous sections. Three zooplankton samples were collected in each site using a 9.5 cm diameter tube sampler. Each of the three subsamples was pooled by passage through a 64 µm mesh filter. Storage and processing of zooplankton and invertebrate samples was as described in previous sections. In addition to zooplankton and benthic macroinvertebrate samples the macroinvertebrate communities associated with the surface of coarse woody habitat were sampled from wooded sites. Woody debris was sampled for macroinvertebrates by first enclosing individual branch segments (N = 3 per site) in a 64 µm mesh bag and clipping the segment. Samples were then lifted from the water and invertebrates were removed using a soft nylon brush. Fish communities were sampled via three passes within the enclosed area using a backpack DC electrofisher. All collected fish were identified to species and measured for total length. Community data sets including fish species, macroinvertebrate, and zooplankton densities were analyzed using discriminant function analysis to examine the degree to which habitats could be distinguished based on the density of each taxa found. Fish communities were analyzed separately by lake due to known differences in community composition while invertebrate communities were pooled across lakes. Individual taxa were included in discriminant functions using a stepwise selection procedure and all groups with a p-value <0.10 were included in final functions. When discriminant functions indicated significant effects of individual taxa these were further examined using ANOVAs to test for differences among habitat types. When significant univariate ANOVAs were found Fisher's Protected LSD was used to separate means and determine specific differences among habitats.

Woody Habitat Pond Experiments

Two trials of an experiment designed to examine the importance of woody habitat to fish communities were conducted in one-tenth acre ponds at the Sam Parr Biological Station. The first was conducted from June 2008 through August 2008 and the second was conducted overwinter from fall of 2008 through the spring of 2009 to examine the role of woody habitat on largemouth bass and bluegill growth and survival. Five ponds contained four individual clusters of woody habitat consisting of 9-17 individual deciduous tree limbs combined to cover an area of roughly 20 square meters (range 19-35 m^2). The four clusters were constructed within each pond so that the total coverage approximated 30% of the pond bottom. The remaining five ponds contained no wood. Ponds were treated with an herbicide to prevent the growth of any vegetation during the course of the experiment. In the first experiment golden shiners (80 between 60-65 mm), bluegill (115 between 35-70mm) and largemouth bass (5 between 200-300mm) were introduced to each of 10 ponds on June 8, 2008. Temperature, dissolved oxygen, pH, chlorophyll a, phosphorus, zooplankton, and macroinvertebrates were sampled biweekly. The experiment ended in August 2008 when the ponds were drained and all remaining fish were measured. Weight, length and number of survivors of each species of fish were determined to assess growth as well as survival between the wood and no wood treatments.

In the overwinter experiment, 150 small bluegill (size range 20-50 mm) and 40 large bluegill (size range 70-130 mm) were stocked into each of 8 ponds. Small bluegills were vulnerable to predation whereas large fish were not. Five largemouth bass (size range 140-210 mm) were also stocked into each pond. Temperature, dissolved oxygen, pH, chlorophyll, phosphorus, zooplankton and macroinvertebrates were sampled both at the beginning of the experiment and again at the end of the experiment in late March. The ponds were drained and all of the remaining fish were counted, measured (TL, mm) and weighed (g).

In previous segments, we reported increased growth of bluegill in ponds containing woody debris in the summer experiment. In this segment we begin the analysis of invertebrate communities in ponds with and without woody habitat in an attempt to shed light on the potential mechanisms for increased growth of bluegill. The five most abundant individual zooplankton and sediment associated macroinvertebrate taxa were examined using univariate repeated measures ANOVAs to test for differences in mean density between coarse wooded and non-wooded ponds over the duration of the experiment. We also tested for differences in community composition of macroinvertebrates colonizing the sediments and those found on the surface of woody habitat on two dates using correspondence analysis. These analyses were conducted to test the hypothesis that coarse wood may support a unique macroinvertebrate assemblage.

In the overwinter experiment the percent survival and growth (length and weight) of each bluegill size category and largemouth bass was calculated and analyzed to determine if there were differences in mortality and/or growth between the wood and no wood treatments. In addition, food resource availability (benthic invertebrate density) and water chemistry (chlorophyll a and phosphorus) was examined as possible explanations for any differences observed in mortality or growth.

Dam Escapement

In order to access dam escapement by largemouth bass we sampled downstream of the dam on two reservoirs, Ridge Lake and Forbes Lake via backpack electrofishing. To sample fish escapement from Forbes Lake, we set up three transects in the Skillet Fork River beginning approximately 0.5 miles downstream of the dam on Forbes lake. Each transect was electrofished moving in an upstream direction towards the dam. All fish collected in each transect were counted and measured to the nearest millimeter (TL). The upper caudal fin on all fish was clipped in order to identify fish recaptured in future surveys. The volume of water coming over the dam was also measured, as well as any peak volume that occurred between sampling periods. The downstream area below Ridge Lake dam was sampled in a similar manner. A 200 m stretch of the stream was sampled via electrofishing in an upstream direction and in one transect. Starting in the spring of 2010, all fish escaping over the Ridge Lake spillway were collected in 12.19 m X 5.73 m catch basin with a 2.54 cm mesh gate. The catch basin was seined at regular intervals and after a major rainfall event and the fish collected were measured and checked for pit tags.

FINDINGS:

Vegetation Management Experiment

In this segment, Lake Paradise was successfully planted with the two species of vegetation. American pondweed and wild celery were planted because of availability and higher success in initial plantings. A total of 11 larger cages and 20 small were planted with American Pondweed and 12 large cages and 33 small were planted with wild celery. Differences in survival were observed depending upon species planted and the size and clustering of the cages (Table 4-1). American Pondweed continued to exhibit the highest survival of all species planted. The 2009 planting occurred in July and the evaluation of the planting was performed shortly after in August. Percent cover was lower than observed in the initial plantings, however due to the close proximity of the assessment to plantings, we cannot fully evaluate the success until the spring/summer of 2010. American pondweed continued to survive the best of the initial planting when evaluated in the fall of 2009 (29% mean coverage). No other species had significant survival through this time. Plant cover was the highest in the large exclosures (mean cover =

24%) followed by the small dispersed cages (mean cover = 16%) and small clustered cages (mean cover = 9%). Large cages appear to be most effective at establishing plants as well as use less material to build. In 2009, large cages had similar percent cover as the small cages, but this is only based on preliminary estimates performed shortly following planting. The perimeter of vegetation on Lake Paradise was 21% vegetated in 2007 and has fluctuated from 57% in 2008 to 40% in 2009. Most of the shoreline vegetation is water willow and densities are influenced by water level changes. The plantings have begun to increase the variety of vegetation found in Lake Paradise and will potentially increase the overall vegetation found on the lake in the future.

In addition to evaluating the vegetation in the enclosures we examined the density of fish and benthic invertebrates associated with vegetated and non vegetated enclosures. The density of fish collected from vegetated cages was higher than non vegetated cages (Table 4-2). The density of fish also varied with plant type. Fish density was highest in wild celery then American pondweed. The highest density was observed in a single cage with sago pondweed, but this was the only cage of sago due to low survival of sago. Similar trends were found in the benthic macroinvertebrate densities. Density of invertebrates was higher in the vegetated cages than non vegetated cages (Table 4-2 B). Invertebrate density varied by vegetation species with the highest being sago pondweed, followed by wild celery and American pondweed. In general, prey fish and invertebrates appear to be found in greater density in the vegetated cages and the vegetation plantings may produce preferred habitat for young-of-year fish. However, few largemouth bass were observed in vegetated cages and benefits are greater for other species.

We evaluated the rehabilitation effort at Dolan Lake by examining the catch rates of gizzard shad and common carp, the fish targeted in rotenone treatments. CPUE of gizzard shad from electrofishing dropped from 35.3 fish/hr in 2005 to 2.0 fish/hr in 2008 and 1.6 fish/hr in 2009 and carp CPUE dropped from 0.8 in 2005 to 0.0 in 2008 and 2009. Gizzard shad populations have declined, but were not eradicated and may rebound in the future. Larval gizzard shad were observed in sampling conducted on Dolan Lake in May therefore some level of reproduction is occurring. Although carp numbers were not high in electrofishing samples prior to the drawdown, we have not observed carp in any sample since the rehabilitation effort. In addition, larval carp were not observed in any of the monthly sampling in Dolan Lake. Decreasing gizzard shad and carp densities should allow water quality changes and reduce feeding and uprooting of vegetation allowing the density of plants to increase. In 2007, 76% of Lake Dolan’s shoreline contained vegetation. Vegetated shoreline increased to 93% in 2008 providing evidence that vegetation may be increasing.

In this segment, we continued to monitor the 13 lakes to examine the role of vegetation in determining largemouth bass recruitment. Vegetative cover ranged from 0-100% in the study lakes (Table 4-3). Lake vegetation has varied among lakes, but lakes maintained their high, medium or low vegetation designation throughout the pre-treatment time period (2007-2009). Percent of the lake area that was vegetated continued to be significantly correlated with the perimeter of the shore that is vegetated (Spring: $r = 0.77$; $P = 0.005$; Fall: $r = 0.79$; $P = 0.003$). Both vegetated area and perimeter were also significantly correlated from the spring to the fall for both percent vegetated area ($r = 0.82$; $P = 0.002$) and vegetated perimeter ($r = 0.89$; $P < 0.001$). We also continued to monitor larval fish, juvenile, and adult fish communities as well as zooplankton and benthic macroinvertebrates to assess the effect of aquatic vegetation. CPUE was calculated from electrofishing samples for young-of-year largemouth bass (< 200 mm), adult largemouth bass (> 200 mm), and all bluegill (Table 4-4). Mean annual density was also calculated for total zooplankton, total benthos, and total larval fish as well as larval bluegill and gizzard shad. These variables were then examined for correlation with the vegetated area and perimeter of each lake. Unlike previous results, young-of year largemouth bass CPUE from electrofishing was significantly correlated with the percent of the lake perimeter that is vegetated in both the spring ($r = 0.79$; $P = 0.004$) and the fall ($r = 0.65$; $P = 0.03$). We will continue to monitor vegetation densities, largemouth bass populations, fish assemblages, prey resources and lake characteristics in vegetation addition, removal and control lakes.

Vegetation and Woody Habitat Enclosures

Discriminant function analysis indicated that fish community composition was a significant predictor of habitat types in Lincoln Trail Lake (Pillai's Trace = 0.67; df = 2,6; $P = 0.04$). Further examination of discriminant functions indicated that bluegill density alone could correctly classify 89% of sites. Univariate tests indicated that bluegill densities differed significantly among habitats (ANOVA; $F_{2,6} = 6.11$; $P = 0.04$). Post hoc tests indicated that vegetated areas had significantly higher bluegill densities than open shorelines ($P = 0.01$) while wooded enclosures had intermediate densities. In Lake Paradise discriminant analysis indicated that fish community composition was a marginally significant predictor of habitat types (Pillai's Trace =0.61; df = 2,6; $P = 0.06$). Examination of ordination plots indicated that white crappie density was the driving factor behind discriminant results. Subsequent univariate tests indicated a marginally significant overall effect of habitat type on density of white crappie (ANOVA; $F_{2,6} = 4.75$; $P = 0.06$). Post hoc comparisons indicated that white crappie density was significantly higher in wooded habitats than in either open or vegetated sites (all $P < 0.05$).

Analysis of invertebrate communities indicated significant differences among habitat types when data was pooled across lakes. Across lakes discriminant function analysis indicated that zooplankton community composition was marginally effective in classifying habitat types (Pillai's Trace = 0.32; df = 2,15; $P = 0.06$). Univariate tests found that cyclopoid copepod density was significantly different among habitat types (ANOVA; $F_{2,15} = 3.53$; $P = 0.05$). Post hoc analysis indicated a 59% increase in density of cyclopoid copepods in wooded sites relative to open sites ($P = 0.02$) while vegetated sites had intermediate densities (Figure 4-1). Macroinvertebrate communities were effective in distinguishing among habitat types (Pillai's Trace = 0.954; df = 9,60; $P = 0.003$). A function incorporating density of Trichoptera and Chironomidae correctly classified 66% of habitat types. Examination of ordination plots and canonical axes indicated that a function that incorporated density of Trichoptera and Chironomidae effectively distinguished invertebrate communities on woody habitat versus those on open sediments and vegetated shorelines. Univariate tests confirmed that density of both Trichoptera (ANOVA; $F_{3,23} = 3.93$; $P = 0.02$) and Chironomidae (ANOVA; $F_{3,19} = 4.23$; $P = 0.02$) were significantly affected by habitat types. Post hoc tests revealed that the density of Trichoptera was nearly six times higher on woody debris than in all other habitat types (all $P < 0.02$; Figure 4-2 *A*) while average density of Chironomidae was two times higher in wooded than in vegetated habitats ($P = 0.06$) and over 3 times higher than on open sediments ($P = 0.02$; Figure 4-2 *B*).

Woody Habitat Pond Experiments

In the summer pond experiment, repeated measures ANOVA's on the five most abundant macroinvertebrate taxa indicated that ponds containing coarse woody habitat and those not containing this habitat had similar average densities of these taxa on surficial sediments (all $P > 0.05$). While densities of macroinvertebrates on the sediments were similar between groups of ponds, correspondence analysis indicated significant differences in macroinvertebrate community composition between assemblages found on sediments and those on the surface of coarse woody structure. Examination of ordination plots indicated that higher densities of several taxa including trichopterans, dipterans, gastropods and ostracods could be found on woody habitat while higher abundance of zygopterans characterized open sediments. Univariate ANOVAs comparing densities of each of these groups between habitats verified trends observed in ordination plots (all $P \leq 0.05$). Repeated measures ANOVA's on the five most abundant zooplankton taxa indicated significant differences between wooded and non-wooded ponds only for cyclopoid copepods. Cyclopoid copepods were significantly more abundant in wooded ponds over the duration of the experiment (R-ANOVA; $P = 0.002$; Figure 4-3).

In the overwinter experiment there were no differences in percent survival between the wood and no wood treatments for small bluegill ($F_{1,6}$=0.81, P=0.4), large bluegill ($F_{1,6}$=0.0, P=1.0) or for largemouth bass ($F_{1,6}$=0.0, P=1.0). In addition growth in both length and weight did not differ between wood and no wood treatments for large bluegill (P>0.2) or largemouth bass (P>0.2). However, small bluegill from the wood treatment grew slightly longer than small bluegill from the no wood treatment ($F_{1,8}$=3.97, P=0.08). Small bluegill growth in weight did not differ between the treatments ($F_{1,8}$=1.74, P=0.2; Figure 4-4). Total density of benthic resources did not differ between wood and no wood treatments ($F_{1,8}$=0.59, P=0.5), nor was there any difference in chlorophyll a ($F_{1,8}$=1.43, P=0.3) or phosphorus concentrations ($F_{1,8}$=0.28, P=0.6).

Dam Escapement

In this segment, one sample was collected from Forbes Lake following a high water event in 2009. Only two large largemouth bass were collected at this time and neither one of them had been captured in previous sampling (Table 4-5). We have not yet established a baseline by which to compare high water results. However we have good data representing extreme high flow events. At Ridge Lake there is some evidence for largemouth bass escapement (Table 4-5). One of the 300+ mm bass collected at Ridge Lake has been confirmed to have come from the lake because it was marked with a pit tag. Dramatically higher numbers of small largemouth bass were present below Ridge Lake compared to Forbes Lake. In addition we have collected good data for 2010 on largemouth bass escapement at Ridge Lake using the new catch basin. Water levels have exceeded the level where water would be discharged over the spillway through July of 2010. While this has resulted in the escapement of bluegill and channel catfish, no large (>200 mm TL) largemouth bass have been observed in the catch basin. One small largemouth bass has been collected, but given the large mesh size of the catch basin gate, it is unclear whether the fish came from the lake or the stream (Table 4-5).

RECOMMENDATIONS:

Additional information on the role of aquatic vegetation to largemouth bass recruitment has been identified as an important goal for management in Illinois. There are a number of potential management strategies for manipulating vegetation that are of interest to managers in Illinois, including chemical treatment to reduce overabundant vegetation and/or nuisance vegetation (e.g. Eurasian milfoil) and habitat restoration to increase vegetation where it is lacking. We have continued a multi lake experiment examining lakes with a range of vegetation densities and have been measuring recruitment of largemouth bass in those systems. We have begun to treat vegetation in Stillwater and Airport Lakes and will begin to monitor changes of vegetation in 2010. Vegetation removal in these lakes has been accomplished primarily through chemical treatments appropriate to reduce the dominant problem vegetation. We will monitor the vegetation in these lakes and evaluate the success of the removal process. We will continue to monitor fish exclusion fences and transplanted vegetation at Lake Paradise and assess if increases in vegetation are observed. We will supplement the plantings from initial years with additional plantings of American pondweed in 2010. Results thus far suggest American pondweed as the species with the highest survival rate and future planting efforts in Lake Paradise will focus on this species. Large cages were shown to produce both larger continuous areas of plants and a greater survival rate of plants inside an enclosure. We recommend the use of larger cages when attempting to establish vegetation in a lake. There is a higher potential for large cages to pull away from the substrate, allowing turtles, carp and other animals to enter the cage and feed on the plants and extra effort should be spent when constructing these cages to ensure they are seated well into the substrate. In the next segment we will expand the size of a number of both small and large cages where plants are established to attempt to spread the vegetation previously planted. During the next several years, we will monitor the lake-wide implications of these vegetation enhancement efforts. In Dolan Lake, the water level was drawn down in an attempt to eliminate carp and gizzard shad. We expect through the removal of these fish and the exposing of the seed bank, that vegetation will increase in this lake. Initial measurements of carp and gizzard shad indicate the fish removal efforts have successfully reduced their numbers. However, gizzard shad numbers have increased since the initial treatment and even though they are low, larval fish have been observed in samples and an increasing number each year. Vegetation at Dolan Lake has increased since the drawdown and fish removal. We will continue to monitor control and treatment lakes and relate changes in largemouth bass recruitment, growth, and abundance to the management practices. We will evaluate largemouth bass recruitment, abundance and growth in lakes with varying vegetation densities in order to identify critical levels of vegetation to target for management.

Previous research in reservoir ecosystems has documented significant effects of littoral habitat on relative abundance and distribution of juvenile and age-0 fishes however a majority of these studies have been conducted on systems with little vegetative or other complex habitat structure (Meals and Miranda 1991; Irwin et al. 1997). While we did not find significant differences in age-0 largemouth bass densities among the microhabitat types sampled in our enclosure surveys, we did find significant differences in the community composition and abundance of potentially important prey items (juvenile bluegills, caddisflies, chironomids, and cyclopoid copepods). Increases in abundance of potential invertebrate and fish prey in vegetated and wooded sites supports the idea that these habitats are important sources of littoral productivity. Differences in fish and invertebrate community structure may influence the foraging success and relative energetic value of different habitats to age-0 largemouth bass and other juvenile fishes. In the future, controlled experiments will evaluate the potential influence of differences in community structure among habitats on feeding of age-0 largemouth bass. These experiments will help to draw links between habitat heterogeneity, biotic community structure and energetics of age-0 fishes.

In summer pond experiment we previously reported evidence that the presence of coarse woody habitat can increase growth of bluegill in a simple aquatic community. Previous research conducted by the INHS has identified the production of bluegill as an important driver of largemouth bass recruitment in Illinois lakes (see Job 101.4) and (combined with our results) may provide a mechanism by which littoral habitat may influence largemouth bass populations. Consistent with field patterns observed among habitats within lakes (see previous section on vegetation and woody habitat enclosures) we found differences in food web components between ponds with and without coarse woody habitat. Abundance of several taxa of macroinvertebrates (e.g. caddisflies, seed shrimp, gastropods) known to be major components of juvenile largemouth bass and bluegill diets were significantly more abundant on the surface of coarse woody debris than open sediments. In addition in both field observations and our pond study coarse wood was associated with increased abundance of cyclopoid copepods. Taxa specific increases in benthic productivity may have important implications for growth and survival of juvenile fishes inhabiting the littoral zone and may explain the observed increases in bluegill growth in the summer pond experiment. While the results of our summer experiment suggest an effect of coarse wood on fish growth and invertebrate community structure it is unclear the relative amount of coarse woody habitat which must be introduced into a system to significantly increase fish and invertebrate production. In future segments we plan to develop pond experiments designed to examine fish growth, and survival as well as invertebrate productivity along a gradient of coarse woody habitat abundance to determine threshold levels by which this habitat may influence the aquatic community. These results will provide a useful baseline for managers attempting restoration activities.

The findings of the overwinter experiment were consistent with those of the summer pond experiment though with a somewhat weaker effect. This is not surprising given that this experiment took place outside the peak-growing season. Small vulnerable bluegill appeared to increase growth in the presence of coarse woody habitat, while large bluegill did not. We found no effect of woody debris on the survival of either size class of bluegill or largemouth bass suggesting, as in the summer experiment, and that many of the effects of woody habitat may be indirect. Small vulnerable size classes of bluegill might be especially likely to change behavior when woody cover is available. We will continue to examine other trophic levels with an emphasis on detecting differences in the invertebrate communities between the wood and benthic sites to determine if woody habitat has the potential to affect the community dynamics of freshwater systems, which may affect growth and survival of largemouth bass.

The assessment of dam escapement is in the very early stages of implementation and evaluation and much more data is needed to draw conclusions about the effect of escapement on largemouth bass populations and recruitment. Additional data will be collected so that a baseline can be established in order to compare largemouth bass numbers after an increased discharge event to largemouth bass numbers during low flow periods. The addition of the new screened catch basin at Ridge Lake will be extremely valuable in providing definitive data on fish coming over the spillway. We will also supplement these data with historical information from Ridge Lake collected over the last 20 years. This information will be compared against water level data which is collected regularly to provide a much better understanding of what hydrological and seasonal conditions lead to the highest escapement patterns for largemouth bass.

Job 101.5 Assessing the impact of angling on bass reproductive success, recruitment, and population size structure.

OBJECTIVE: To assess the level of angling for nesting bass in Illinois and to determine its impact on reproductive success and annual recruitment, as well as to determine how much long term exploitation of Illinois bass has changed the size structure of those populations.

INTRODUCTION:

The growth in the popularity of competitive angling events targeting black bass has been substantial in the United States over the last 40 years with exceptional growth occurring in the past decade. Highlighting this recent growth, about 18,000 events were estimated to occur in North America in 2000 whereas over 32,000 were estimated to occur in 2005 in the United States alone (Kerr and Kamke 2003; Schramm and Hunt 2007). Although tournament rules require the release of captured bass following the conclusion of the "weigh-in," high mortality (>50%) has been reported during tournaments within the last 10 years (Neal and Lopez-Clayton 2001; Gilliland 2002; Wilde et al. 2002a), necessitating investigations into strategies to minimize mortality during these events. Mortality can be capture-related (i.e. hooking mortality) but can also be due to the collective impact of several sub-lethal stressors incurred by bass throughout the tournament process (Kwak and Henry 1995) such as the disturbances sustained during livewell confinement or the weighing procedure. In addition, the sub-lethal physiological disturbances incurred by bass that ultimately survive the tournament process can negatively impact growth (Wendelaar Bonga 1997) and fitness (Schreck et al. 2001; Ostrand et al. 2004) and increase susceptibility to disease (Pickering and Pottinger 1989). Clearly, identifying factors that influence the sub-lethal and lethal consequences of tournaments on largemouth bass and potential avenues to mitigate these impacts is important for the sustainable use of bass fisheries.

Removal of spawning males by angling has been shown to reduce the reproductive success of an individual largemouth bass, often causing brood reduction and nest abandonment (Philipp et al. 1997). However, the population-level impact of reduced reproductive success of some individuals is unclear. In the spring, male largemouth bass (Micropterus salmoides) build solitary, highly visible (depending on water clarity) saucer-shaped nests in the substrate in order to court and spawn with females (Kramer and Smith 1962; Pflieger 1966; Coble 1975). Once spawning is completed, females leave the nesting area and the male remains to provide all parental care of the developing offspring, a period that may last four or more weeks (Ridgway 1988; Cooke et al. 2002). While male bass are providing parental care for their broods, they are extremely aggressive (Ridgway 1988; Cooke et al. 2002) and, therefore, highly vulnerable to many angling tactics (Neves 1975; Kieffer et al. 1995). Even though this vulnerability has never been assessed accurately, many fisheries management agencies have invoked closed fishing periods, catch-and-release regulations, and various length and harvest limit scenarios in an effort to enhance or promote bass reproduction and recruitment (see Schramm et al. 1995). We are assessing the relationship between nesting success and recruitment in Lincoln Trail Lake. In addition, we are also directly testing the effect of angling on recruitment through manipulative pond experiments. The strategy of maximizing reproductive success by protecting successful spawning bass from angling assumes that there is a positive relationship between reproductive success and recruitment, which has not been specifically determined. Also, density-dependent interactions in young-of-the-year largemouth bass may cause populations to compensate for the lost reproductive success of some individuals.

Exploring recruitment in a controlled setting allows us to isolate and test different mechanisms regulating survival. In order to further explore the effects of angling largemouth bass during the spawning period, we continued one pond experiment and began an additional pond experiment during this segment. In the first experiment, we assessed the effects of removing the earliest broods in a population as those have been shown to have the greatest effect on recruitment. There is potential for angling to have a large influence on largemouth bass populations. In particular, competitive tournament fishing for black bass has grown rapidly over the past several years. Previous work has shown high levels of mortality associated with these tournaments in other parts of the United States, but tournament procedures continue to improve. In previous segments, we evaluated the effects of small club style tournaments for largemouth bass. Mortality at small, club-style tournaments at Evergreen Lake was low, and never exceeded 5%. The low mortality and relatively mild physiological disturbances incurred by largemouth bass during club events suggests that these types of tournaments can have minimal impacts on fish compared to larger tournaments if proper care is taken. We also identified nest abandonment rates for fish exposed to tournament angling, catch and release angling and no angling controls. We found almost all fish exposed to tournaments abandoned their nests after 24 hours and 33% abandoned after catch-and release-angling. In pond experiments we saw similar abandonment of the nest. When nests were guarded from predators using screens, fish were less likely to abandon the nest upon return, possibly due to reduced predation on eggs and reduction in brood on a nest. We also reported that increased distance of release from the nest and time off the nest both increased abandonment rates. We also monitored largemouth bass tournaments during the spawning period and post spawn to determine if nesting bass were targeted. We did not observe a shift in the sex of fish depending on season although a large number of ripe and running fish were angled in springtime tournaments. Thus far we have shown effects of tournaments on largemouth bass at the individual level, but how these effects translate into affects on recruitment are unknown. Therefore, we also initiated a second experiment to directly examine the population consequences of tournament angling during the spawning season. In addition we conducted spring largemouth bass tournaments at Ridge Lake in order to examine the affects on tournament angling on largemouth bass recruitment at the lake level. These pond and lake experiments will allow us to further evaluate the potential effects of spring tournament angling on largemouth bass recruitment.

Despite low mortality and stress associated with small tournaments, there can be substantial mortality and sub lethal stress associated with large scale tournaments with extensive weigh-in procedures (Wilde 1998; Allen et. al 2004; Suski et. al 2003; Suski et. al 2004). Due to the stress and mortality associated with these large tournaments, we continued to evaluate the use of paper tournaments to reduce potential negative effects. Paper tournaments allow anglers to release fish shortly after they are caught and in the same vicinity as their capture as well as remove the stress associated with livewell confinement and weigh-in procedures. Little is known about how varying tournament angling pressure can influence the life history traits of largemouth bass populations. Therefore, we are also evaluating the long term influence of tournament activities on populations of largemouth bass. Our objective is to quantify tournament pressure for a number of lakes and examine differences in largemouth bass populations in lakes with varying tournament pressure.

PROCEDURES:

Nest observations

Snorkeling surveys were used to assess bass spawning activity, nest site selection by males, aggressiveness of males guarding a nest, and the level of nest predation in Lincoln Trail Lake. Snorkel surveys commenced on April 14th, 2010 and continued through May 19th, 2010. The six transects have been monitored for several years. Each located nest was given a nest tag and an egg score (1-5). The water depth of the nest was recorded as well as the developmental stage of the offspring. A visual length estimate of the guarding male was noted as well as the presence or absence of a hook wound. The number of predators in the nest was recorded, as well as their size and amount of time spent in the nest. Habitat within a 4m x 4m quadrant around the nest was mapped, making note of substrate, cover and potential nest predators. We also assessed the available habitat within each transect to determine if largemouth bass were exhibiting any substrate selectivity for specific nesting sites. Transects were snorkeled perpendicular to the shoreline and substrate was quantified at 5-meter intervals. At each interval, 5 point estimates were visually assessed for dominant substrate along each transect from 2m of depth to the shore. These data were used to estimate the proportion of each substrate type available within each snorkeling transect and compared to the substrate at each nesting site. A Chi-squared test was used to determine significant variation of used habitat from available habitat in 2006 through 2010. The absolute value of residuals (greater than 1.96) determined which substrate type was used significantly greater than (+) or less than (-) expected. To determine if different nest substrates pose greater risks of predation, percent composition of nests with potential nest predators were separated from nests with no potential predators. A random distribution of selected nest sites would yield equal numbers of nests with and without nest predators.

Manipulative Experiments

The first manipulative pond experiment was designed to assess the effects of disturbance during the spawning period on recruitment. Initiated in the summer of 2009, the goal was to test how the removal of early-spawned fish would affect recruitment, since it has been shown that early, aggressive spawners contribute a greater proportion of their young to the final recruitment. Eight 1-acre ponds were stocked with 22 adult largemouth bass (12 females and 10 males), 30 adult bluegill (15 of each sex), and natural densities of bluegill nest predators. In four ponds, progeny from the first three spawned nests were removed to simulate failed nests of early spawners due to targeted angling practices. At the end of the summer (August), ponds were drained and the resulting young-of-year largemouth bass were counted and measured.

The second experiment, being initiated during the summer of 2010, is aimed at assessing the direct effect of tournament angling during the spawning period on recruitment. Most research on this topic has focused on the effects that angling treatments have on success of an individual bass, but the impact that the culmination of these effects have on recruitment is still relatively unknown. Also, willingness of individual fish to strike a lure and other behavioral factors have yet to be considered when testing angling effects on population recruitment. To address these questions, eight 1-acre ponds were stocked with the same fish densities listed above. During the spawning period, half of the ponds were subjected to simulated tournament angling pressure comparable to that which would be expected on heavily fished systems. Successfully angled fish, including nesting and non-nesting males and females, were kept in livewells for a period of time to simulate the typical treatment of largemouth bass during tournaments before being released. Ponds will be drained at the end of the summer so that recruitment can be assessed. Otoliths from young-of-the-year bass will also be analyzed to determine if angling pressure influenced hatch date in treatment ponds.

Influence of Spring Tournaments on Reproduction

Tournament angling for largemouth bass has been shown to cause nest abandonment for fish angled off the nest. However the population level affects of nests abandonment have not been examined. In this segment we continued an experiment at Ridge Lake examining the effects of tournament-style angling of nesting largemouth bass in a population previously unexploited during the spawning season. Ridge Lake has a controlled creel operated by the Illinois Natural History Survey. The lake has traditionally been closed to fishing until mid May and no tournaments had been conducted at Ridge Lake prior to the beginning of this experiment. In the early spring of 2007, seven angling tournaments were conducted during the spawning season (April 22 - May 22) on Ridge Lake, prior to the opening of the regular public angling season. During each tournament, six anglers spent four hours (24 angler hours per tournament) targeting largemouth bass. All fish caught were brought back to the dock, measured for total length, weighed, and scales were collected. The fish were then kept in a lakeside pen for 2 hours following the tournament when they were released back into the lake. Recruitment of largemouth bass was measured as the relative CPUE from fall electrofishing samples and mean density of young-of-year largemouth bass collected in seines in late August and early September. Additionally, a complete creel census has been conducted on Ridge Lake during the open angling season of each year. Prey resources were also monitored at Ridge Lake throughout the season (zooplankton, larval fish, seine, benthos cores, and water quality; see job 101.4 for methods). We will monitor largemouth bass populations and prey resources in Ridge Lake through both tournament and non-tournament years and examine the relationship between spring angling tournaments and lake wide recruitment. No tournaments were conducted in 2008 and 2009. Largemouth bass tournaments were conducted in the spring of 2010 and data from these tournaments will be summarized in future reports.

Paper Tournaments

In previous segments we conducted paper tournaments on 4 lakes in Illinois to determine their potential for reducing largemouth bass mortality through the elimination of the weigh-in. In this segment we have compiled data from an additional tournament conducted on Ridge Lake in the spring of 2010. Anglers were asked to record the total length of each fish caught to the nearest quarter inch. All fish were also measured for total length and weight using a typical weigh-in. Anglers were then ranked under a variety of scoring criteria, including the official tournament results (total weight of fish > legal limit), total paper length (sum of total length of all fish caught), total paper weight (sum of weight estimated from paper lengths of all fish caught), paper length from legal fish (sum of lengths from fish over the legal limit), and paper weight from legal fish (sum of weight estimated from paper lengths). Paper lengths were converted to paper weights using a length weight regression developed from largemouth bass collected in Illinois Lakes by electrofishing. Once anglers were ranked under each scenario, the difference of each ranking from the official weigh-in ranking was calculated as the absolute deviation from the weigh-in rank. We compared the differences in ranking among the tournament scenarios in order to evaluate each technique.

Long-Term Effects of Tournaments

We began to evaluate how long-term harvest and varying tournament pressure has impacted the population size structure of largemouth bass populations through selection-driven changes in life history traits. Electrofishing transects were performed in twelve lakes in the spring and all largemouth bass were collected, measured for total length and weighed. Lakes were categorized as high tournament pressure, medium pressure, or no tournament pressure lakes. Scales were collected from each largemouth bass and were aged by two independent readers to determine mean length at age for fish in each lake. In spring electrofishing samples, sex was determined when possible as well as maturity status (mature or immature) and spawning status (ripe, running, or spent). Largemouth bass were collected from each lake for size ranges that were too small to determine sex and maturity status in the field and returned to the laboratory. Tournament pressure was determined for lakes where we could identify all tournament activity on a lake. We have coordinated with DNR biologists, lake managers and tournament organizers to obtain records of all tournaments conducted on a number of lakes. We also worked with tournament organizers and lake managers to obtain tournament results and weigh-in data for all tournaments conducted. When all weigh-in results were not available, we estimated weigh-in results using similar tournaments from the same lake.

We will examine the intensity of tournament activity at each lake and evaluate the abundance and size structure of the associated largemouth bass population.

FINDINGS:

Nest Observations

A total of 62 nests were observed between 4/14/2010 and 5/19/2010 in Lincoln Trail Lake. The first nests were observed after temperatures reached 18^{o}C, and more nests were identified the following week as the water temperature increased (Figure 5-1). Nesting peaked early and declined throughout the spawning period. Nest substrate use was significantly different than available habitat in all four years ($P<0.001$). In 2010, gravel, cobble, and pebble were used more than expected, while wood, leaves, and sand was used less than expected (Table 5-1). Across all years examined for nest substrate, cobble, pebble, and gravel were used more than expected based on availability, while vegetation was used less than expected. There was a greater likelihood of nest predation when bass spawned on gravel and cobble and a lesser likelihood when bass spawned on vegetation, wood, and detritus (Figure 5-2).

Manipulative Experiments

In the manipulative experiment conducted in 2009, ponds that had the early cohort removed had approximately 5 times greater recruitment than ponds with the early cohort intact (Figure 5-3). Although more plentiful, treatment fish were smaller at the end of the summer than control fish (Figure 5-3). These results show that the early cohort depresses survival of later-hatched cohorts during the first summer of life; however, overwinter survival may restrict survival of later-hatched cohorts to age-1.

Influence of Spring Tournaments on Reproduction

Tournaments were conducted at Ridge Lake during the 2007 spawning season and fish populations and prey resources were compared to non-tournament years in 2006, 2008, and 2009 (Table 5-2). Anglers caught 448 largemouth bass during 168 angler hours for a mean tournament CPUE of 2.67 fish/angler-hour (range 1.00 – 4.42 fish/angler-hour). Recruitment was assessed as CPUE of young-of-year largemouth bass from fall electrofishing and was greater in 2007 than in non tournament years (Figure 5-4). CPUE of adult largemouth bass and bluegill however were lower in 2007. These results are based on one year of tournament fishing and three years of closed fishing and any interpretation should be made cautiously until additional data are collected. These preliminary results suggest that spring tournaments may not adversely affect reproduction. We will continue to conduct spring tournaments at Ridge Lake during the bass spawning period in alternating years to evaluate changes in recruitment that may be attributed to tournament activity.

Paper Tournaments

In this segment we assessed data from 8 paper tournaments that ranged from 14 to 39 participating anglers (Table 5-3). Results from the paper tournaments were similar to the official weigh-in results when only fish greater than the legal limit are included. Mean deviation in rank for each angler was slightly greater than 1 for both total paper length and converted paper weight of legal sized fish (Figure 5-5). An average of 1.1 anglers that were ranked in the top five in the official weigh-in were no longer in the top 5 due to the use of paper tournament results for legal fish (Table 5-4). These results suggest that paper tournaments can rank anglers similarly to official weigh-in results and may be used to replace the weigh-in and still identify the tournament winners. When paper tournaments considered all fish caught in angler rankings, rank deviation for each angler increased to around 4. Similarly the number of top 5 anglers that dropped out of the top five increased. Paper tournaments would allow organizers to consider fish that were caught that are too small to keep in a traditional weigh-in. These methods of evaluating who is the best angler will dramatically change the ranking of angler and may be a better or alternative measure of fishing skill rather than only considering legal sized fish. Paper tournaments can also evaluate traditional measures of winners based on anglers with the largest fish. Paper lengths for both tournament scenarios were similar to the weight results and converting paper lengths to weights is not necessary to rank anglers.

Long-Term Affects of Harvest

We have identified 12 lakes where all tournament activity conducted on the lake is known. Tournament pressure was assessed by the number of tournaments conducted on a lake, the mean number of participants, and the total hours fished in each tournament (Table 5-5). This was used to calculate the total angler hours for each tournament. These lakes were separated into lakes with no tournaments (none; angler hours = 0), intermediate tournament pressure (medium; mean angler hours = 3,443; range = 972 – 7,632), and high tournament pressure (high; mean angler hours = 14,289; range = 10,741 – 18,130), We examined CPUE from spring electrofishing samples for young-of-year and largemouth bass greater than 14 inches in each lake and compared catch rates across the three tournament pressure groups. CPUE was variable among all tournament pressure groups (Figure 5-6). High and medium lakes had similar CPUE for both young-of-year and adult largemouth bass, with non tournament lakes having a lower CPUE of adult fish, but higher CPUE of young-of-year. When tournament effort is regressed against largemouth bass CPUE there is no relationship for adult fish (Figure 5-7 A.) or young-of-year fish (Figure 5-7 B.). Lakes with no largemouth bass tournaments had higher recruitment of young-of-year fish, but did not have as abundant of a largemouth bass population over 14 inches, which is the legal minimum size limit in many lakes in Illinois.

RECOMMENDATIONS:

Largemouth bass tournament angling continues to be popular and we have continued to evaluate the effects of these tournaments on fish populations and recruitment. In previous segments, we have demonstrated that largemouth bass can be targeted during nest guarding and that these angled fish are likely to abandon the nest. Thus far, we have been able to assess spawning activity and assess recruitment during seven years at Lincoln Trail Lake. Monitoring has allowed us to determine the duration of spawning as well as the relative number of nests formed each week. During the next segment we will analyze otoliths collected during the summer of 2010. The relative number of bass collected in the fall from each spawning date will be compared to the number of new bass nests to determine differences in relative survival. A number of factors related to spawning date could influence survival. Earlier spawned fish may have a size and growth advantage over later spawned fish. Alternatively, the early-spawned fish may negatively affect the survival of later-hatched cohorts. We will continue to evaluate these factors in future segments and address their importance in determining recruitment.

Monitoring largemouth bass nesting in Lincoln Trail has also allowed us to determine where nesting is occurring and the types of habitat bass prefer for spawning. Continuing to evaluate preferences in spawning habitat and available habitat for bass spawning is important in order to understand what factors may influence nesting success. Management strategies such as improving nesting habitat may be important in lakes where spawning success is low due to lack of appropriate habitat. This data will continue to be utilized to evaluate spawning substrate and habitat preferences and to examine factors that may influence the aggressiveness and success of nesting bass. In addition, habitat adjacent to the nest may be important for YOY bass for feeding and avoiding predation. Additional data will aid in the understanding of the importance of spawning conditions to survival and help develop management strategies to protect spawning fish.

Pond experiments provide evidence of how angling largemouth bass during the spawning season can impact recruitment dynamics and reduce the size of the year class. Manual brood reduction resulted in lower survival of YOY, and surviving YOY were similarly sized compared to YOY in populations that did not experience brood reduction. We found no evidence of compensatory survival or growth in YOY in response to these manipulations; however, we did find compensatory survival in the manipulative experiment conducted in 2009. Although more individual YOY survived in ponds without the early cohort, surviving individuals experienced reduced growth, which will make them more susceptible to size-selective mortality, especially overwinter. These results suggest protecting the early cohort from angling pressure could be used as an alternative to closed seasons. We will continue to monitor the manipulative pond experiment began in 2010 evaluating the population consequences of tournament angling and will report results in the next segment.

In this segment we have continued to evaluate largemouth bass tournaments and their procedures and assess how they affect fish populations. To assess the effects of angling practices and tournaments on largemouth bass reproduction and recruitment we will continue experiments initiated at Ridge Lake. No experimental angling tournaments were conducted on Ridge Lake in 2008 and 2009 and were used as control data. We conducted a second season of angling tournaments in the spring of 2010 and will summarize these data in future segments. We will continue to conduct tournament angling in the spring of alternating years to provide additional replication. At this point, there is too little replication to interpret the data collected thus far. We will continue to collect additional years of data and present findings in future segments.

Paper tournaments have the potential to remove the stress associated with livewell confinement and weigh-in procedures, and reduces the time a male is removed from nesting sites. We have demonstrated that paper tournaments can accurately rank anglers as well as allow tournaments to include smaller fish and should be considered as an alternative to traditional weigh-ins especially during high temperature times of year and the spawning season. In addition, paper tournaments allow the inclusion of fish that are caught, but shorter than the legal limit. These fish are ignored in a traditional weigh-in, but provide an alternative way to evaluate who is the best angler. We have shown the potential of paper tournaments and encourage organizers to consider their use in future tournaments.

We will continue to evaluate how varying tournament pressure and angler harvest has impacted the size structure and abundance of largemouth bass populations through selection-driven changes in life history traits. We will continue to sample lakes with varying tournament pressure for largemouth bass. In this segment we identified 12 lakes where we can identify all of the tournament activity. We will continue to monitor tournament activity at these lakes as well as compile weigh-in results. These data will allow us to further examine the relationships between tournaments and fish populations and determine if they can influence fish populations. We will also incorporate creel data in order to assess fishing pressure on these lakes and relate them to largemouth bass size structure. In addition we will incorporate FAS data from DNR biologist electrofishing sampling to supplement INHS electrofishing data. We will continue to determine sex and ages of largemouth bass in lakes with varying fishing exploitation. We will examine how angling activities influence sex specific characteristics such as growth, longevity, and age of maturity. Using this data, we will be able to make predictions about how angling will affect recruitment of largemouth bass and adult populations. This will allow us to identify the potential impacts of tournaments and harvest to life history characteristics in largemouth bass populations.

Job 101.6. Evaluating the impact of spawning refuges, habitat manipulations, harvest regulations and other management strategies on largemouth bass recruitment in Illinois.

OBJECTIVE: To develop a model to evaluate the effects of various angling scenarios and pressures on Illinois bass recruitment and size structure. To evaluate the effects of fish refuges on Illinois bass recruitment and size structure.

INTRODUCTION:

Largemouth bass can be vulnerable to anglers during spawning and reproductive success may depend on the level of angling stress the fish undergoes during this period. This has sparked a recent controversy among anglers as to whether or not bed fishing (angling fish off the nest) is detrimental to bass populations. Our recent research (Job 101.5) suggests that angling largemouth bass off nests can cause nest abandonment, which results in the failure of the nest to produce offspring. Many states have implemented closed seasons or spawning refuges, which are closed to fishing in an attempt to alleviate this problem. It is unclear if these management techniques are appropriate for Illinois reservoirs.

Clinton Lake is an approximately 2000-hectare lake that is operated as both a power plant cooling lake and a recreational lake. In the fall of 2001, a portion of the lake adjacent to the Clinton Lake Power Plant was permanently closed to boaters and anglers. This closed area serves as a refuge for largemouth bass from angling. Otter Lake is a 310-hectare lake that operates as a water supply and recreational lake. Jeffrey Pontnack (District 14/15 Fisheries Biologist) and Dennis Ross (General Manager of Otter Lake Water Commission) proposed closing two large bays to fishing and boating, providing a spawning and fishing refuge for largemouth bass and other fish species. The refuges may be beneficial to largemouth bass, by increasing spawning success and decreasing fishing mortality. We are using these lakes to evaluate the success of refuges in increasing the density and size structure of the largemouth bass populations.

There are many potential harvest regulation strategies that can be used to help manage bass populations, including size limits, closed seasons, and spawning refuges. Each of them can have a different impact on the population, either by affecting size structure or density. Some regulations have the potential to impact recruitment more than others, but right now, we cannot make accurate predictions. Increasing the quality of angler catch or harvest rates are common rationales for harvest regulations (Paukert et al. 2007). However, compilation of 91 studies using minimum-length limits and slot-length limits concluded that most studies were conducted over too short a period and did not include creel data to document if a regulation increased angler catch rates (Wilde 1997). Many regulation decisions are not influenced by information available on black bass biology (Paukert et al. 2007). There is a need for further research examining the effects of angling regulations (Novinger 1984; Wilde 1997; Paukert et al. 2007).

In this job, we are examining the use of closed seasons and refuges in two lakes and comparing largemouth bass recruitment and densities before and after implementation of the refuge. We are also evaluating current regulations used in Illinois largemouth bass management in order to determine the effects on population size structure and density as well as angler catch rates.

PROCEDURES:

Population abundance and size structure of largemouth bass are being assessed in Otter and Clinton Lake using spring and fall electrofishing and seining. Clinton Lake refuge was closed in 2001 and samples were taken both before and after implementation of the refuge. Samples collected on Clinton during 1999 – 2001 represent pre-refuge and 2002 to present represent post-refuge. In this segment, post refuge electrofishing transects and seines hauls were performed in Clinton Lake during the spring and fall of 2009 and the spring of 2010. Two, thirty minute electrofishing transects and two seine hauls were performed inside the refuge on each sampling date. Three transects were also electrofished and seined outside of the refuge. Sites outside of the refuge were located adjacent to and at approximately 2 lake kilometers from the refuge. Seining was conducted using a 9.2-m bag seine pulled along the shoreline at fixed transects. In addition to Clinton Lake, two potential refuges sites were identified in Otter Lake and will be closed to fishing beginning June 2010. In this segment we continued sampling Otter Lake to monitor pre refuge largemouth bass populations. One 30 minute electrofishing transect and one seine haul were conducted in each proposed refuge location. In addition, three control sites were sampled (1 electrofish transect and 1 seine haul in each) within the lake as reference locations. One reference location is located near each proposed refuge, and the final reference location at the midpoint between the refuge sites. Fish were identified to species and total length was recorded. All fish were counted and up to 50 fish were measured for each species. All largemouth and smallmouth bass collected inside refuge sites were given an upper caudal fin clip in order to determine if fish in the refuge move into adjacent areas of the lake. Catch per unit effort (CPUE) was then calculated as the number of fish per hour of electrofishing and number per square meter area seined.

Largemouth bass angling regulations in Illinois Lakes are also being evaluated. In previous segments, regulations on lakes with largemouth bass population data from Job 4, (including recruitment, abundance and size structure) were used for initial analyses. In this segment we have included additional lakes with differing regulations identified from the FAS database. Data collected through IDNR fall surveys were collected and compiled. The FAS data base was reduced to the lakes that were sampled in the fall of 2007 using AC shoreline electrofishing and had regulations posted in the IDNR Fisheries Bulletin. The lakes were categorized by their existing regulations into five categories, Standard (14” length limit, 6 fish creel), Lowered Bag (14” length limit, <6 fish bag limit), Raised Length (>14” length limit, 6 fish bag limit), Raised Length/Low Bag (>14” length limit, <6 fish bag limit), and Slot (no fish harvest slot). These lakes were then compared across regulation type for differences in CPUE of young-of-year largemouth bass, CPUE of largemouth bass greater than 14 inches, and proportional stock density (PSD) with stock size being 200 mm and quality size being 300 mm. In addition we determined the number of memorable (510 and over) sized fish in electrofishing samples.

FINDINGS:

Mean CPUE for largemouth bass in Clinton Lake from 1999 through 2001 was 25.5 fish per hour of electrofishing. This is in the lower range of our study lakes, which have a range of CPUE from 20.9 to 67.3 fish per hour. As a result, there is the potential for an increase in abundance of largemouth bass in Clinton Lake from the establishment of the refuge. Sampling at sites inside the refuge in 2003 through 2010 yielded a much higher CPUE than sites outside the refuge (Table 6-1). In addition, CPUE was greater inside the refuge after closing than samples taken before the refuge was closed. This suggests that bass numbers are increasing in the refuge potentially due to the elimination of fishing pressure. With the increased number of adult bass in the refuge, we would expect to also find an increase in young of year production inside the refuge, however this is not being observed consistently in our seine and electrofishing samples. Continued assessment of young-of-year bass will be used to assess if the refuge is enhancing natural recruitment in Clinton Lake. No clipped fish were observed in electrofishing or seine samples taken outside of the refuge. This implies that there is little or no movement of fish from the refuge to the open portion of the lake. We will continue to assess the potential lake-wide effects the refuge may have as a tool for managing bass populations in future segments.

We continued monitoring future refuge and reference sites in Otter Lake during this segment. In fall of 2009 and spring of 2010, we observed slightly higher catch rates of largemouth bass in the refuge sites than the control sites in the remainder of the lake (Table 6-1). The proposed refuge sites appear to be in areas with good bass abundance and closing these areas to fishing has the potential to increase recruitment. We will assess if limiting disturbance of these fish during nesting may increase spawning success and yield larger year classes. Effects of a refuge may be easier to detect on Otter Lake than on Clinton as well due to its smaller size. The refuge blockades were put in place in June of 2010 and we will begin to evaluate their success in future segments.

A total of 92 lakes were sampled in the fall of 2007 using AC electrofishing gear. Of those 92 lakes, 80 lakes had special regulations listed in the Illinois Department of Natural Resources fishing guide. The 80 lakes were divided into groups and categorized by their existing regulations into six categories, Standard (14” length limit, 6 fish creel, n = 25), Lowered Bag (14” length limit, <6 fish bag limit, n = 13), Raised Length (>14” length limit, 6 fish bag limit, n = 12), Raised Length/Low Bag (>14” length limit, <6 fish bag limit, n = 22), and Slot (protected harvest slot, n = 8). Lakes where slot limits are enforced had the highest CPUE of both young-of-year fish and fish greater than 14 inches. Lowered bag limit lakes with a 14 inch minimum size limit had the second highest CPUE of YOY fish, but the lowest CPUE of 14 inch and bigger fish and no memorable sized fish sampled. Lakes with raised length limits had the highest CPUE for memorable sized fish (1.1 fish/hr), second highest CPUE of fish greater than 14 inches and CPUE of young-of year fish similar to the standard regulation. The presence of large fish in lakes with raised length limits resulted in those lakes having the highest PSD score (Figure 6-2). Standard length limit lakes had slightly lower PSD score, but was similar to raised length limits in both CPUE and PSD. Preliminary analysis of the FAS database showed that lakes with standard length and bag limits have reasonably good bass populations. There may be some value to raising length limits to protect larger fish which was observed by reduced length limit lakes having higher adult CPUE and the highest PSD score. Lowering bag limits, both alone and with raised length limits, resulted in lakes with fewer big fish and lower PSD scores. Lakes with a slot limit had the greatest overall CPUE with high numbers of young-of-year and adult largemouth bass. This however resulted in a reduced PSD due to the large number of young fish. Longer time series will be needed to determine if the size structure observed is a result of the regulation or the reason for implementing the regulation.

RECOMMENDATIONS:

There are many potential harvest regulation strategies that can be used to manage bass populations, including size and creel limits, closed seasons, and spawning refuges. Each of them, either singly or collectively, can have a different impact on the population, either by affecting size structure and/or abundance. Some regulations have the potential to impact recruitment more than others, but right now, we cannot make accurate predictions. Other management options include habitat, prey, and predator manipulations. Thus far we have been evaluating a spawning /fishing refuge on Clinton and Otter Lakes. We plan to continue our evaluation by conducting seine hauls in the spring and fall at sites within the refuge and sites on the main lake to estimate the abundance of young-of-year largemouth bass. We will also conduct electrofishing transects in the spring and fall within the refuge and on the main lake to monitor adult largemouth bass populations. Data will be compared after the refuges were initiated to those from the same sites during the years preceding the implementation of the refuges. Bass captured in both seine hauls and electrofishing transects inside the refuges will also be marked with a caudal fin clip on Clinton and Otter Lakes. All bass collected will be examined for existing clips in order to determine if bass in the refuge are moving into the main lake. These studies will provide information regarding the value of fishing refuges for increasing largemouth bass recruitment.

Adaptive management experiments to evaluate habitat manipulations, including vegetation and the role of woody debris (described in Job 4) are also being evaluated as part of this job. Management experiments are manipulating vegetation (e.g. plantings and removals) to examine changes in largemouth bass growth and survival. The experiment includes control lakes, as well as treatment lakes to either increase or decrease the density of aquatic vegetation. These experiments will be used to make management recommendations regarding vegetation and woody habitat in order to increase largemouth bass recruitment.

We will continue to develop and analyze a large database of lakes with differing regulations. We will use FAS data collected by IDNR district biologists as well as creel data to determine if regulations are having the desired effect on largemouth bass populations, as well as angler behaviors. These combined datasets offer nearly twenty years of creel survey and population assessment data collected under project F-69-R. In future segments we will incorporate lakes with INHS sampling and creel data to develop a long term database of lakes with fish community data and creel sampling. The number and frequency of lakes where angling creels were performed will limit the number of lakes that can be included in this aspect of the study. We will create an extensive database that can be used to examine differences in electrofishing catch, and a reduced database including creel data. We will contact DNR district biologists and determine when regulations were initiated and use creel and FAS data to compare catch rates of anglers, CPUE from electrofishing and size structure of largemouth bass in these lakes before and after the regulation was put in effect. In doing so, we hope to better understand the value of differing management regulations on lakes throughout Illinois. These data can then be used to guide future discussions about various management experiments that might be implemented.

Job 101.7. Analysis and reporting.

OBJECTIVE: To prepare annual and final reports summarizing information and develop management guidelines for largemouth bass in Illinois.

PROCEDURES and FINDINGS: Data collected in Jobs 101.1-101.6 were analyzed to develop guidelines for largemouth bass regarding stocking and management techniques throughout Illinois.

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Table 2-1. Cost of producing fish for three lakes in Illinois stocked for 5 years with both intensively reared and extensively reared fish. Extensively reared fish were produced in ponds and fed zooplankton and fathead minnows, whereas intensively reared fish were produced in raceways and fed pelleted food.

Lake	Lake Area (acres)	Rearing Method	Cost per fish stocked	Mean Total Stocking Cost	Cost Per Acre
Jacksonville	476	Extensive	$0.46	$6,900.00	$14.50
Shelbyville	11,100	Extensive	$0.46	$7,148.60	$0.64
Walton Park	30	Extensive	$0.60	$375.00	$12.50
Jacksonville	476	Intensive	$0.15	$2,250.00	$4.73
Shelbyville	11,100	Intensive	$0.15	$5,309.55	$0.48
Walton Park	30	Intensive	$0.15	$93.75	$3.13

Table 2-2. Stocking information for four lakes stocked with largemouth bass both at the boat ramp and dispersed into habitat throughout the lake. CPUE is catch per hour from electrofishing transects conducted in the fall after stocking and the subsequent spring.

Lake	Stocking Date	Boat Ramp Stocking			Dispersed Stocking		
		# Stocked	Fall CPUE	Spring CPUE	# Stocked	Fall CPUE	Spring CPUE
Charleston	8/15/2008	3500	2.0	0	3500	2.0	0.4
	8/25/2009	3500	0.8	0	3500	0	0.7
Homer	8/16/2007	1400	0	0	1400	0.3	0
	8/24/2009	1000	0	0	1000	0.3	0
Mingo	8/16/2007	3400	0.7	0	3400	2.0	0
	8/14/2008	2150	5.7	0	2150	3.7	0.7
	8/24/2009	2125	0	0	2125	0.3	0
Otter	8/15/2007	7650	0	0	7650	0	0
	8/13/2008	11400	0.8	0	11400	0.2	0
	8/25/2009	7650	0.4	0	7650	0	0

Table 2-3: Select characteristics of 13 Illinois lakes monitored annually from 1998-2005 to examine effects of supplemental largemouth bass stocking. Information for most parameters taken from Austen et al. (1993) with the exception of Total Phosphorous (TP) which represents seasonal means (TP – June-August), from data collected during 1998 sampling.

Waterbody	Treatment	Max Depth (m)	Surface Area (ha)	Watershed Area (ha)	Residence Time (yrs)	Conductivity (umhos)	TP(ug/L)
			Gizzard Shad Absent				
Sterling	Reference	4.37	28.6	72	8.5	625	45
Lincoln Trail	Reference	10.67	56.9	850	0.9	225	95
Walnut Point	Reference	9.75	21.8	103	0.3	383	147
Murphysboro	Stocked	9.75	58.1	697	1.0	192	93
Le-aqua-na	Stocked	6.71	17.3	1012	0.3	467	157
Kakusha	Stocked	3.66	22.9	550	0.3	426	200
			Gizzard Shad Present				
Dolan	Reference	5.18	70.0	431	0.5	265	463
Paradise	Reference	4.88	57.6	4686	0.1	454	181
Lake of the Woods	Reference	6.70	10.5	206	0.6	481	105
Woods	Stocked	5.79	11.2	465	0.2	420	166
Charleston	Stocked	4.88	132.2	560	0.002	362	150
Homer	Stocked	7.32	32.7	3755	0.1	N/A	384
Pierce	Stocked	10.06	61.2	8150	0.4	462	243

Table 2-4: Multiple Before-After, Control-Impact (MBACI) analysis to test for changes in food web components through time following supplemental stocking of largemouth bass. Mean difference for each parameter between stocked and unstocked (control) lakes are shown before and after stocking. P-values indicate significance (Trt x Period term) from the repeated measures ANOVA.

Parameter	Difference Before	Difference After	df	F	*P*
		Non-Shad Lakes			
Littoral Prey Fish Density (#/m^2)	3.03(±27.61)	-1.29(±1.45)	1, 4	8.50	0.03
Adult Prey Fish CPUE (N/Hr)	55.72(±273.98)	-5.21(±229.36)	1, 4	0.01	0.93
Cladoceran Density (#/L)	6.59(±34.30)	20.38(±12.18)	1, 4	2.12	0.16
Cladoceran Length (mm)	0.007(±0.23)	-0.12(±0.05)	1, 4	4.07	0.11
Chaoboridae Density (#/L)	-0.34(±0.20)	0.14(±0.19)	1, 4	0.64	0.47
Total Benthos Density (#/m^2)	-2693.12(±3373.36)	4907.33(±2581.39)	1, 4	11.47	0.03
Chironomidae Density (#/m^2)	-2938.00(±958.66)	-677.32(±675.97)	1, 4	5.35	0.08
Ceratopogonidae Density (#/m^2)	-587.19(±334.22)	-207.71(±315.43)	1, 4	2.89	0.16
Chlorophyll a (ug/L)	4.97(±21.05)	15.06(±23.67)	1, 4	0.28	0.67
Total P (ug/L)	69.40(±175.42)	172.52(±119.23)	1, 4	0.36	0.26
Secchi Depth (m)	-1.08(±2.15)	-0.93(±0.19)	1, 4	0.41	0.85
		Shad Lakes			
Littoral Prey Fish Density (#/m^2)	1.33(±4.00)	0.25(±0.39)	1, 5	0.11	0.34
Adult Prey Fish CPUE (N/Hr)	-79.29(±123.39)	52.49(±71.35)	1, 5	1.07	0.36
Cladoceran Density (#/L)	1.11(±19.33)	-0.03(±4.86)	1, 5	0.16	0.72
Cladoceran Length (mm)	-0.02(±4.00)	0.00(±0.04)	1, 5	0.75	0.72
Chaoboridae Density (#/L)	0.40(±0.24)	-0.09(±0.18)	1, 5	0.61	0.47
Total Benthos Density (#/m^2)	1876.74(±1596.64)	-741.36(±1226.94)	1, 5	3.33	0.13
Chironomidae Density (#/m^2)	1878.96(±585.03)	-30.33(±331.08)	1, 5	8.08	0.04
Ceratopogonidae Density (#/m^2)	-61.59(±179.66)	-168.01(±143.48)	1, 5	0.36	0.56
Chlorophyll a (ug/L)	-14.74(±127.27)	-4.90(±9.04)	1, 5	0.49	0.56
Total P (ug/L)	-32.69(±187.71)	-9.78(±22.35)	1, 5	0.04	0.69
Secchi Depth (m)	0.03(±1.51)	0.08(±0.23)	1, 5	0.36	0.82

Table 3-1: Background frequencies (pre-stocking) of largemouth bass MDH B2:B2 genotype determined from Little Grassy Fish Hatchery and six lakes in Illinois prior to stocking for 6-7 years from 1998 to 2005.

Lake	N			Allele Frequency	
	1:1	1:2	2:2	1	2
Forbes	81	49	28	0.67	0.33
McClean	23	34	32	0.45	0.55
Murphy	80	12	6	0.88	0.12
Sam Parr	75	16	10	0.82	0.18
Shelby	158	45	8	0.86	0.14
Walton	66	11	8	0.84	0.16

Table 3-2: The influence of stocked fish on the MDH B2 allele frequency as a function of lake size for five study lakes analyised in this study. Influence was based on the average percent increase in allele frequencies in each of the lakes compared to initial allele frequency.

Lake	Lake size (hectares)	Initial MDH B2 allele frequency	Ending MDH B2 allele frequency	Percentage increase in MDH B2 allele frequency	Influence
Shelbyville	4494	0.14	0.16	17%	Minor
Forbes Lake	226	0.33	0.38	14%	Minor
Lake Murphysboro	58	0.12	0.21	76%	Moderate
Sam Parr Lake	58	0.18	0.36	99%	Moderate
Walton Park	12	0.16	0.42	164%	Major

Table 4-1: Mean percent cover for each species of vegetation planted in Lake Paradise in June and July of 2008 (A.) and July of 2009 (B.). Percent cover was visually assessed in August of 2008, June of 2009 and August of 2009 in each of three sizes of enclosure (large, small dispersed, and small clustered).

A. Planted in 2008

Veg Planted	Size	Number Planted	Percent Veg Cover		
			Fall 2008	Spring 2009	Fall 2009
American Pondweed	Large	6	78	5	51
American Pondweed	Small Disp.	12	61	2	18
Chara	Large	6	1	0	0
Chara	Small Disp.	12	0	0	0
Chara	Small Cluster	4	0	0	1
Coontail	Large	7	16	1	0
Coontail	Small Disp.	16	3	0	0
Coontail	Small Cluster	4	0	0	0
Sago	Large	4	23	0	0
Sago	Small Disp.	34	12	6	0
Sago	Small Cluster	16	12	0	2
Wild Celery	Large	13	22	1	0
Wild Celery	Small Disp.	58	15	1	0
Wild Celery	Small Cluster	52	15	1	0

B. Planted in 2009

Veg Planted	Size	Number Planted	Percent Veg Cover
			Fall 2009
American Pondweed	Large	11	19
American Pondweed	Small Disp.	20	11
Wild Celery	Large	12	4
Wild Celery	Small Disp.	30	5
Wild Celery	Small Cluster	3	0

Table 4-2: Density of fish from backpack electrofishing and density of invertebrates from stovepipe core samples associated with vegetation enclosures planted in Lake Paradise in 2008 and 2009.

A.

Vegetation	n	Density of Fish (#/m2)
	Fish	
American Pondweed	21	0.71
Coontail	1	0.80
Sago	1	2.55
Wild Celery	6	0.94
All vegetated cages	29	0.82
No Veg	26	0.70
	Benthic Invertebrates	
American Pondweed	12	22672
Sago	1	44012
Wild Celery	9	35250
All vegetated cages	22	28788
No Veg	9	17610

Table 4-3: Data from spring and fall vegetation assessments on 13 Illinois lakes. Vegetation on each lake was mapped using GPS to estimate the area and perimeter of the vegetated area of the lake. Percent vegetated area and perimeter are the proportion of the entire lake. Dashes indicate data still being analyzed.

Lake	Type	Lake Area (m^2)	Lake Perimeter (m)	Area Vegetated				Percent of Lake Vegetated			
				Area (m^2)		Perimeter (m)		Area (m^2)		Perimeter (m)	
				Spring	Fall	Spring	Fall	Spring	Fall	Spring	**Fall**
Airport	Removal	89246	1171	60534	89148	1065	2275	68	100	91	100
Dolan	Drawdown	302869	5335	-	-	-	-	-	-	-	-
Forbes	Control	2056612	29364	-	-	-	-	-	-	-	-
Kakusha	Removal	192665	3256	0	0	0	0	0	0	0	0
Le-Aqua-Na	Control	175825	2709	27392	724	1609	129	16	0	59	5
Lincoln	Control	584546	10033	103330	150099	8278	10010	18	26	83	100
LOTW	Control	103090	2259	489	105	72	104	0	0	3	5
Paradise	Planted	706098	7287	31667	32415	3014	2921	4	5	41	40
Pierce	Control	647830	6406	131161	175657	5955	5507	20	27	93	86
Ridge	Control	53141	1483	18922	12865	1426	970	36	24	96	65
Stillwater	Removal	89363	2215	89363	89363	2215	2213	28	100	100	100
Walnut	Control	215810	9396	1374	7943	228	740	1	4	2	8
Woods	Control	127217	3241	0	0	0	0	0	0	0	0

Table 4-4: CPUE for young-of-year and adult largemouth bass in 13 lakes with varying vegetation densities (see Table 4-3). In addition, mean larval fish, zooplankton, and benthic macroinvertebrate density for each lake from spring, summer and fall samples.

Lake	Type	Mean Fall Electrofishing CPUE (#/hr)			Larval Fish Density (#/m^3)			Mean Total Zooplankton Density (#/L)	Mean Total Benthos Density (#/m^2)
		YOY LMB (<200mm)	BLG	LMB >200mm	Shad	Lepomis	Total		
Airport	Removal	25.8	68.6	3.0	0.0	3.0	3.0	230.8	721.5
Kakusha	Removal	7.6	62.9	12.4	0.0	0.1	0.1	1499.6	326.6
Stillwater	Removal	30.5	34.8	5.3	0.0	0.0	0.2	416.9	1206.3
Dolan	Drawdown	6.0	91.3	48.0	0.8	21.1	21.9	208.2	2764.9
Paradise	Planted	18.2	100.0	19.0	1.1	6.2	7.3	639.5	93.9
Forbes	Control	5.5	101.3	30.3	2.0	1.9	4.2	1233.4	3479.9
Le-Aqua-Na	Control	21.0	92.0	28.3	0.0	2.0	2.1	314.1	874.5
Lincoln	Control	28.7	77.3	25.0	0.0	4.0	4.2	284.4	1732.7
LOTW	Control	19.5	98.9	25.4	3.5	12.3	15.8	564.4	280.3
Pierce	Control	41.0	28.0	23.0	0.8	0.2	1.0	299.9	928.5
Ridge	Control	52.5	80.6	19.2	0.0	9.2	9.2	1150.7	1180.6
Walnut	Control	22.3	90.0	15.0	0.0	6.6	6.7	388.8	2525.7
Woods	Control	8.7	100.0	14.0	2.0	3.6	5.7	550.4	308.6

Table 4-5: Number of bass from each 100 mm size class found in the streams below the dams of both Forbes Lake and Ridge Lake during 2008-2010. The sampling at Ridge Lake in 2010 is the total of 3 sampling dates.

Date	300+ mm	300-200 mm	200-100 mm	100-0 mm
Forbes Lake				
4/24/08	3	2	3	0
5/19/08	3	1	2	3
6/13/08	0	2	0	2
4/28/09	0	2	0	0
Ridge Lake				
6/10/08	4	1	1	25
4/16/10 to 6/7/10	0	0	0	1
Total	10	8	6	31

Table 5-1: Chi-squared residuals for largemouth bass nesting substrate. Absolute values greater than 1.96 indicate substrates that were significantly over expressed (positive values) or under expressed (negative values) relative to their availability.

Year	Vegetation	Wood	Sticks	Leaves	Detritus	Sand	Gravel	Cobble	Pebble
2006	**-1.97**	**5.06**	**4.58**	**-2.26**	**-2.70**	-0.69	-0.30	**3.11**	**3.83**
2007	**-2.49**	0.27	0.30	**-1.79**	-1.09	0.91	**2.27**	**3.38**	**3.28**
2008	**-2.75**	0.84	0.35	1.07	-0.77	-1.36	**3.51**	**2.84**	1.69
2010	0.95	**-2.46**	-1.11	**-2.14**	0.46	**-3.05**	**9.36**	**15.99**	**4.56**

Table 5-2: Fish community and prey resource information from Ridge Lake in three years where no angling tournaments occurred and one year where spring angling tournaments were conducted. Electrofishing CPUE is the number of fish captured from whole lake electrofishing transects performed in the fall of each year. Larval fish, zooplankton, and benthos densities are the mean from May through September of each year.

Year	Type	Mean Fall Electrofishing CPUE (#/hr)			Larval Fish Density (#/L)	Zooplankton Density (#/L)	Benthos Density (#/m^2)
		YOY LMB (<200mm)	BLG	LMB >200mm			
2009	No Tourn.	52.5	80.6	19.2	9.2	1150.7	1180.6
2008	No Tourn.	39.2	96.8	49.9	0.11	458.8	3212
2007	Tournament	59.2	67.2	52.3	1.15	399.4	1239.71
2006	No Tourn.	29.1	50.8	41	0.5	352.2	3070

Table 5-3: Tournament information from the 8 paper tournaments conducted on Clinton Lake, Lake Sara, Mill Creek Lake, Ridge Lake, and Lake Shelbyville. Paper tournament participants recorded the length of each fish caught in quarter inch increments.

Lake	Date	Start Time	End Time	# of Anglers	Total number of Fish Weighed In	# of Paper Participants
Clinton	7/10/2004	5:45	13:45	20	6	14
Lake Sara	5/22/2004	5:45	13:45	24	27	16
Lake Sara	5/23/2004	5:45	13:45	25	27	16
Mill Creek	5/8/2004	6:30	14:30	26	4	14
Ridge	4/17 to 5/17/2010	10:00	14:00	39	171	39
Shelbyville	6/12/2004	5:30	13:30	22	9	13
Shelbyville	6/13/2004	5:30	13:30	23	8	16
Shelbyville	5/22/2005	6:00	15:00	65	152	33

Table 5-4: The number of anglers that were ranked in the top five in the official weigh-in that were no longer ranked in the top five under a variety of paper tournament scenarios. Paper tournaments were conducted on 5 lakes and a total of 8 tournaments where anglers recorded the length of each fish caught to the nearest quarter inch. Paper tournaments for all fish included data from all fish caught, while paper tournaments of legal fish included only fish larger than the legal length limit of the lake.

Lake	Date	Paper Weight All Fish	Paper Length All Fish	Paper Weight Legal Size	Paper Length Legal Size
Clinton	7/10/2004	0	0	0	0
Lake Sara	5/22/2004	4	4	2	2
Mill Creek	5/8/2004	1	2	0	0
Ridge	4/30/2010	1	1	3	3
Shelbyville	6/12/2004	1	1	1	1
Shelbyville	6/13/2004	1	3	0	0
Shelbyville	5/22/2005	2	2	2	2
	Mean Total	1.4	1.9	1.1	1.1

Table 5-5: Tournament activity fat 12 lakes in Illinois and information on tournament effort and catch data was recorded.

Lake	Tournament Pressure	Number of Tournaments	Mean Number of Participants	Mean Hours Fished	Mean # of Fish Weighed in	Mean Weight (lbs)
Lincoln Trail	None	0	-	-	-	-
Lake of the Woods	None	0	-	-	-	-
Woods	None	0	-	-	-	-
Walnut Point	None	0	-	-	-	-
Evergreen	Medium	16	29	5.6	15	2.3
Bloomington	Medium	14	34	5.4	25	2.7
Forbes	Medium	25	43	7.1	42	2.0
Mattoon	Medium	10	22	4.5	14	2.1
Coffeen	High	49	27	8.0	53	2.1
Mill Creek	High	94	29	6.5	48	1.9
Sangchris	High	48	28	8.0	55	1.9
Shelbyville	High	33	67	8.2	70	2.0

Table 6-1: Catch per unit effort of largemouth bass from electrofishing samples performed in Clinton Lake and Otter Lake in both refuge sites that were closed to fishing and control sites. Pre-refuge sites refers to samples performed in proposed refuge areas prior to closing.

A. CLINTON LAKE

Year	Control		Refuge	
	Spring	Fall	Spring	Fall
		Pre-refuge		
1999	19.8	24.4	56	24
2000	32.4	5.5	18	0
2001	26	48.7	10	22
		Refuge Closed 9-11-01		
2003	21.5	23.8	-	87.5
2004	20.7	28.3	42	146
2005	27.5	18.3	33	25
2006	14.1	18.5	24	50
2007	18.3	32.7	23	44
2008	36	36	38	110
2009	15	33.7	75	55
2010	13	-	15.6	-

B. OTTER LAKE

Year	Control		Refuge	
	Spring	Fall	Spring	Fall
		Pre-refuge		
2007	-	37.4	-	55.2
2008	23.2	37.7	26.5	46
2009	22	52.3	31.5	61
2010	37.6	-	35	-

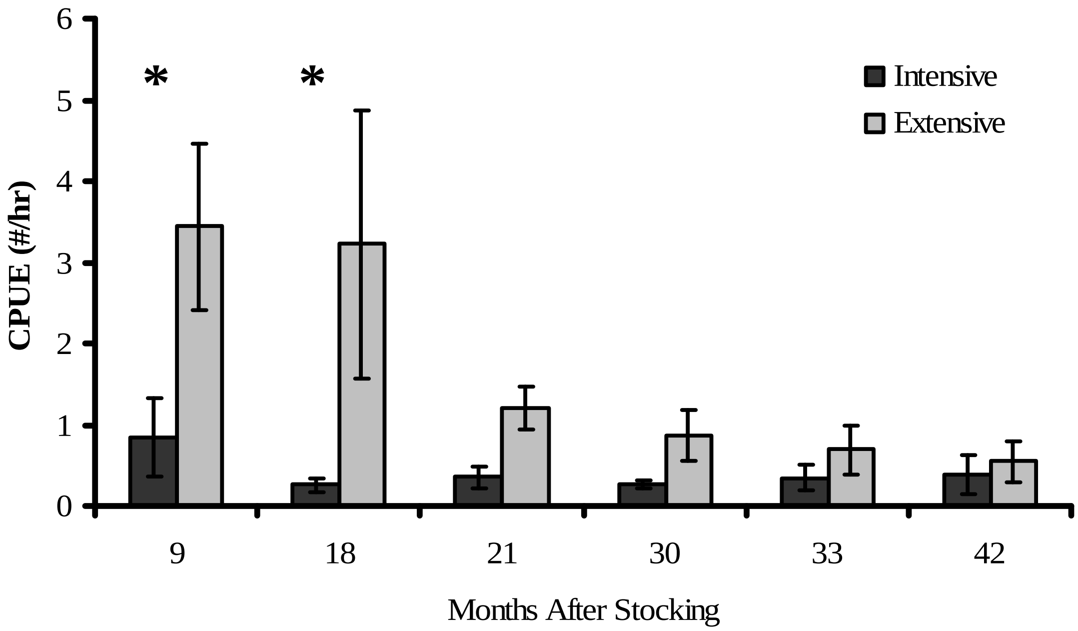

Figure 2-1: Mean CPUE of intensive and extensive fish collected in AC electrofishing samples following stocking. Samples were collected in the fall following stocking (9) and each spring and fall for 5 years thereafter. The star indicates time periods where there were significant differences in CPUE of intensively and extensively reared fish.

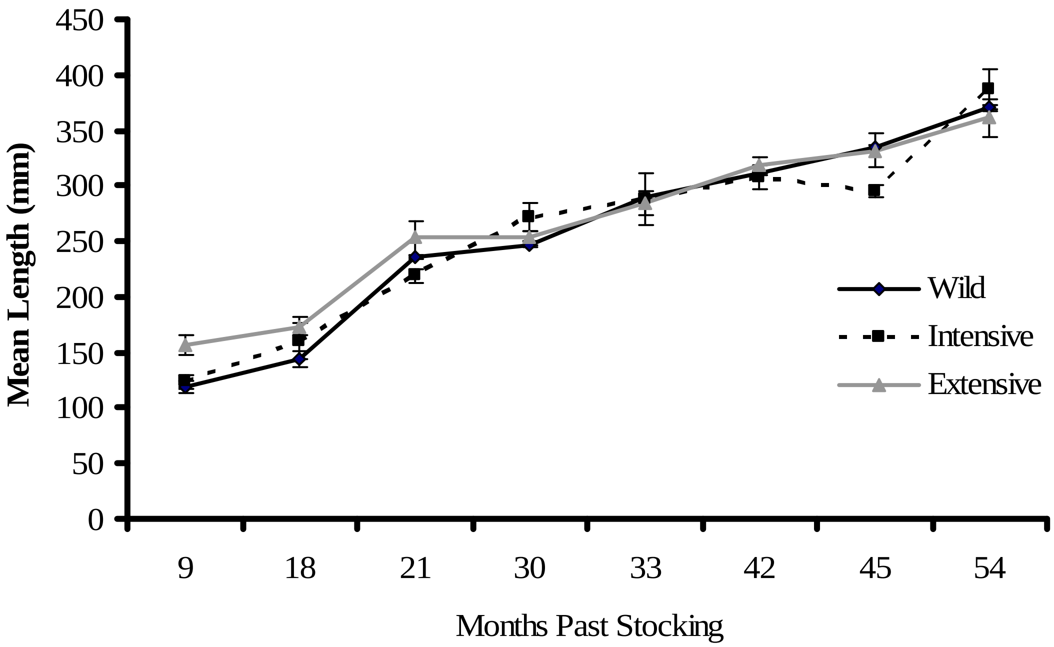

Figure 2-2: Mean length of intensive, extensive, and wild fish collected in AC electrofishing samples in the months following stocking. Samples were collected in the fall following stocking (month 9) and each spring and fall for 5 years there after..

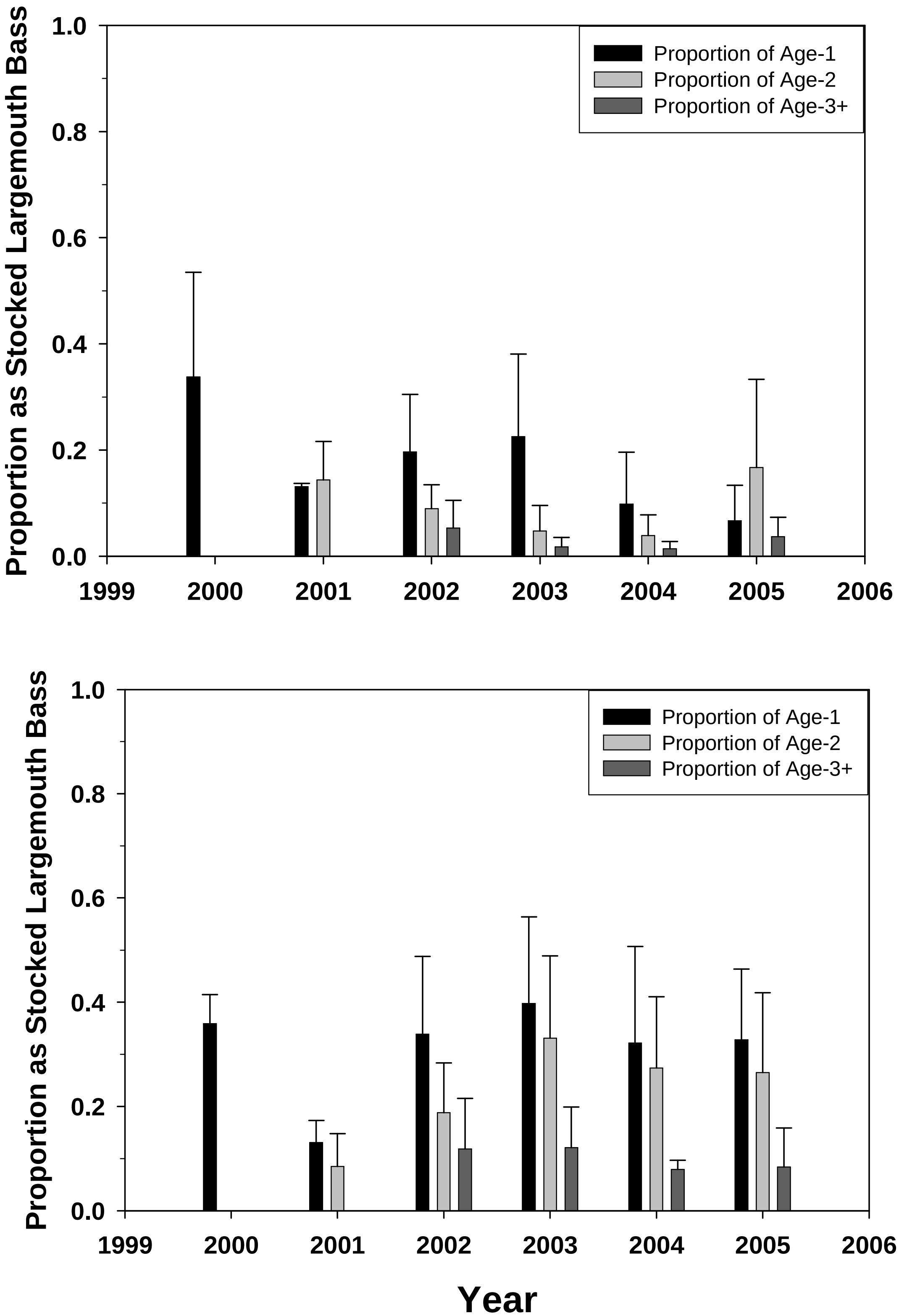

Figure 2-3: Mean proportion of total collected largemouth bass comprised of stocked fish by year and age group for impoundments where gizzard shad were absent (A) and present (B). Data from standardized fall electrofishing (see methods for description) conducted 2000-2005.

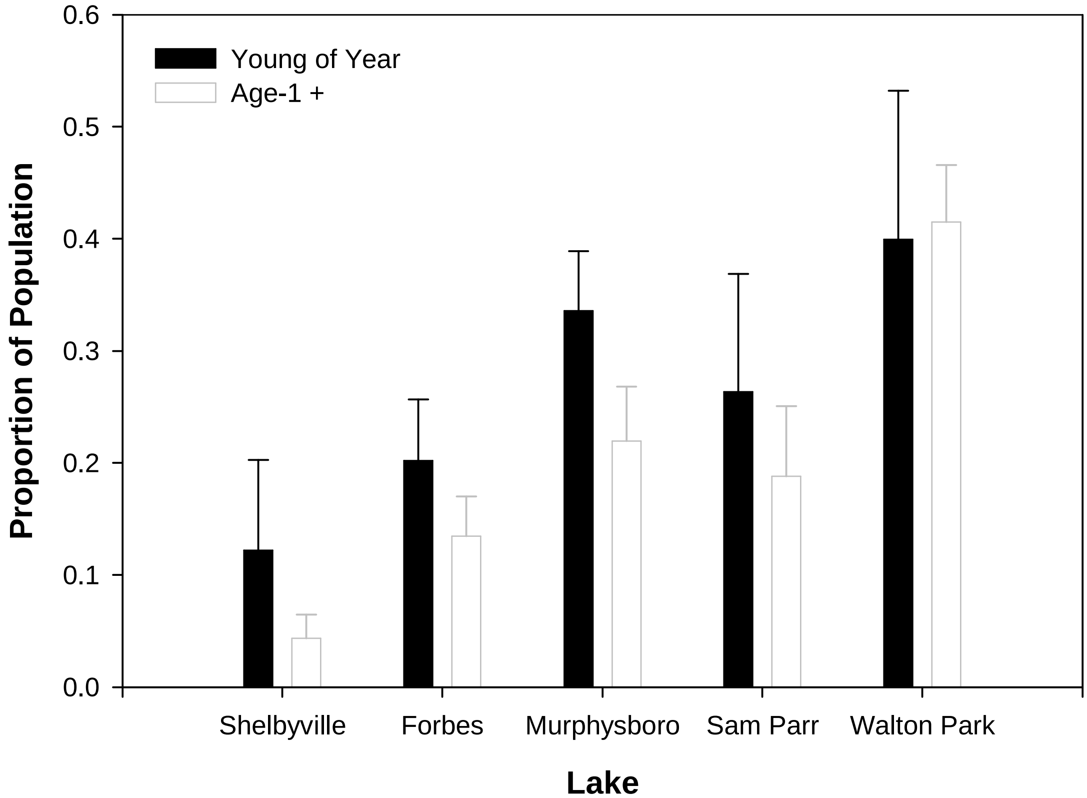

Figure 3-1: Proportion of the largemouth bass population in each lake composed of stocked fish as young of year and at age-1 and older. Each proportion is the average of years 2002 through 2007 for each lake.

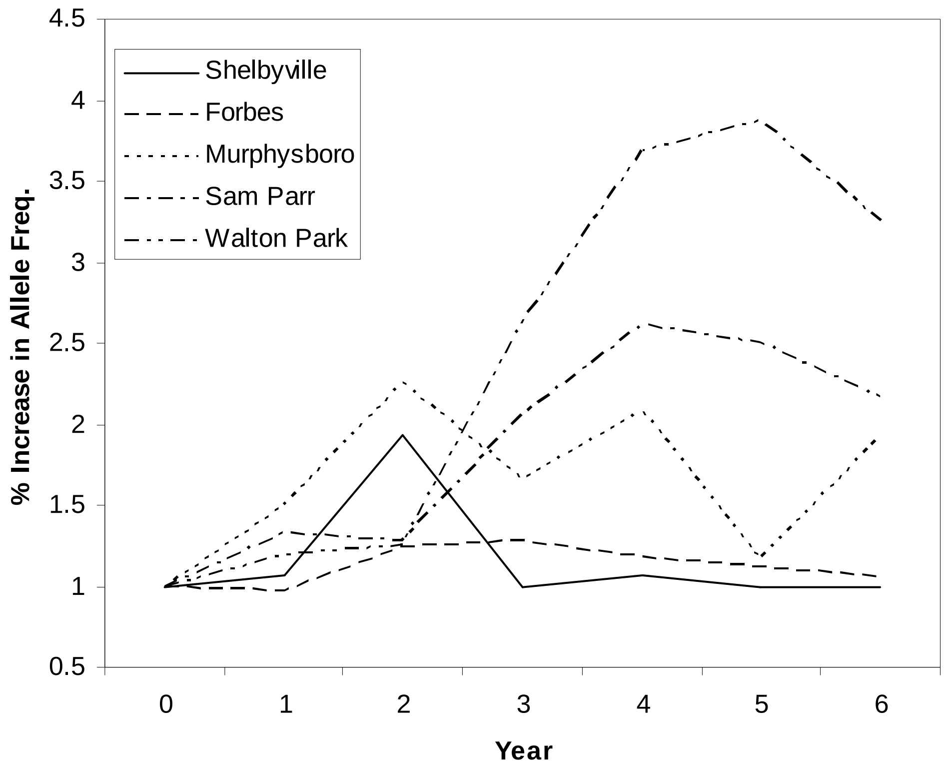

Figure 3-2: Frequency of the B2 allele in the five study lakes previous to stocking and in 2002-2007 during which stocked bass were expected to be contributing to reproductive population.

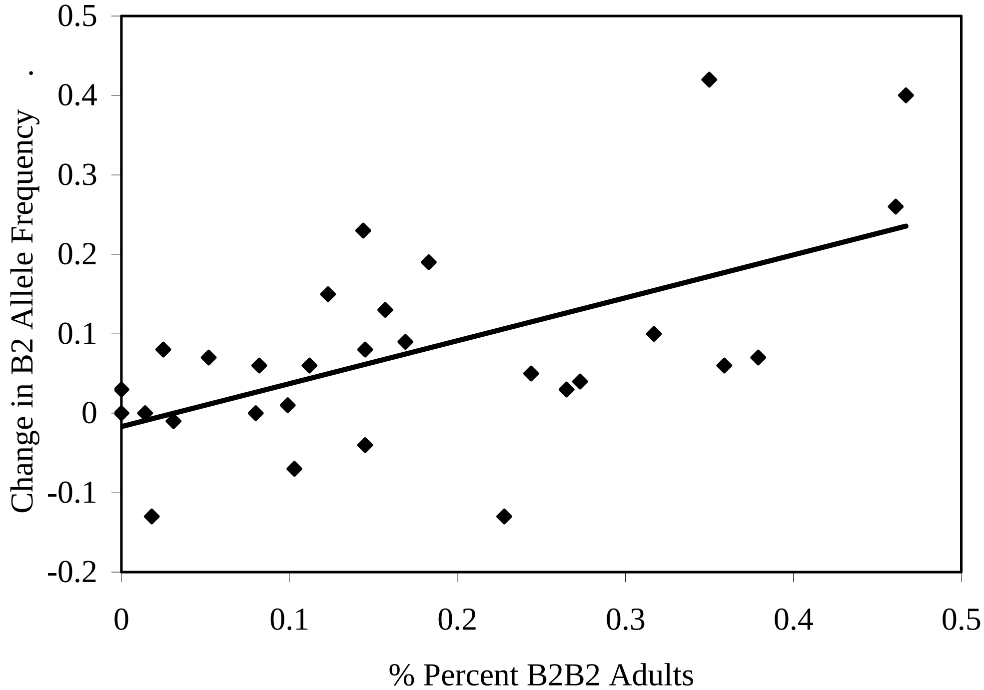

Figure 3-3: Change in B2 allele frequency with the proportion of B2B2 adults in the population for five study lakes for each year between 2002 and 2007.

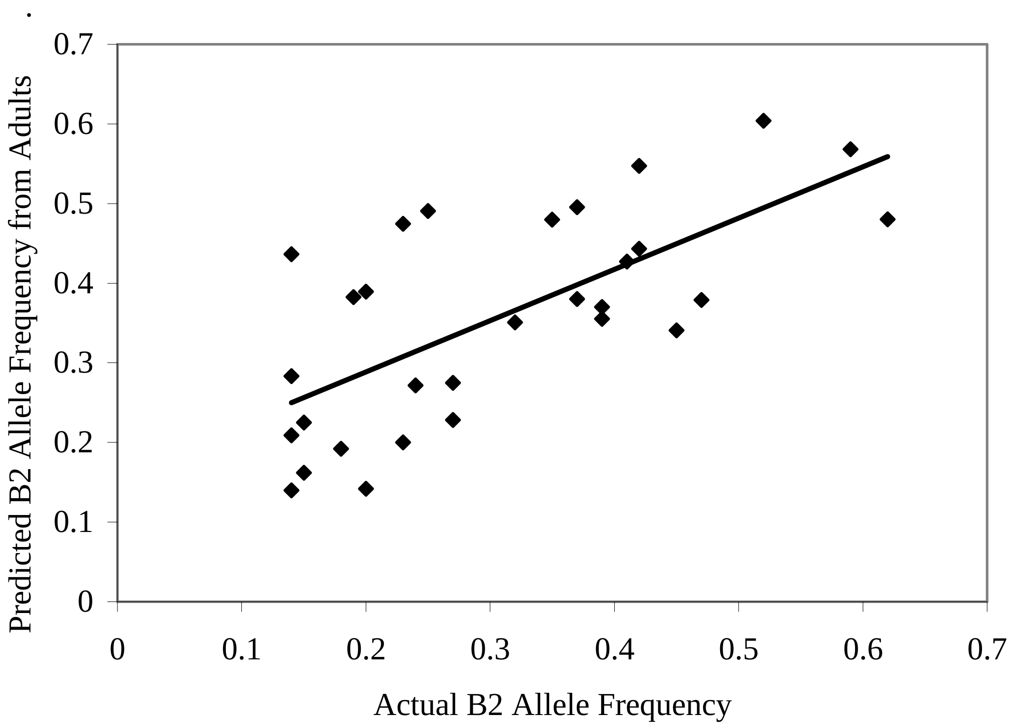

Figure 3-4: Regression of actual and predicted B2 allele frequency based on stocked adult fish for five study lakes for each year from 2002-2007.

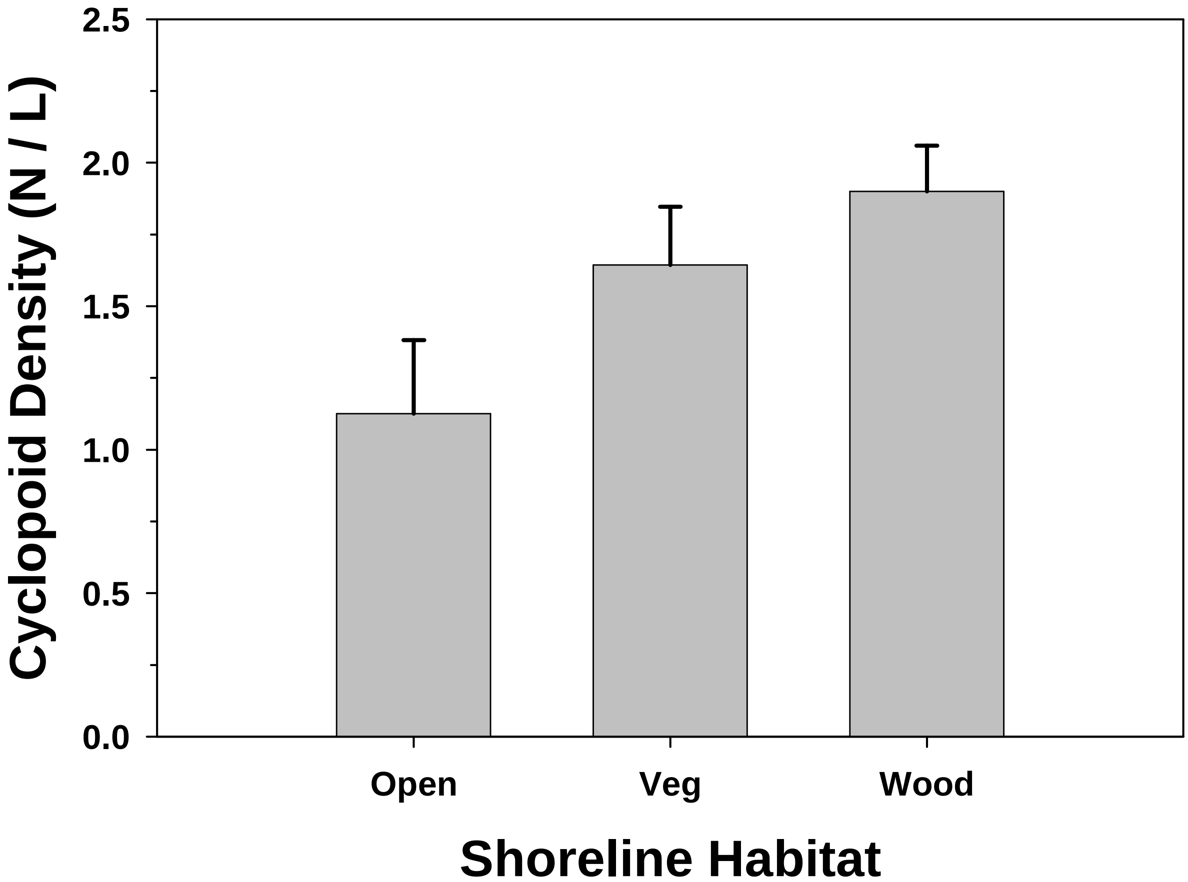

Figure 4-1: Mean density of cyclopoid copepods sampled from open, vegetated (Veg), and wooded microhabitats across two Illinois Lakes during August of 2009. Each bar represents an average of three sites of each category from each lake (total N = 6 samples per habitat type).

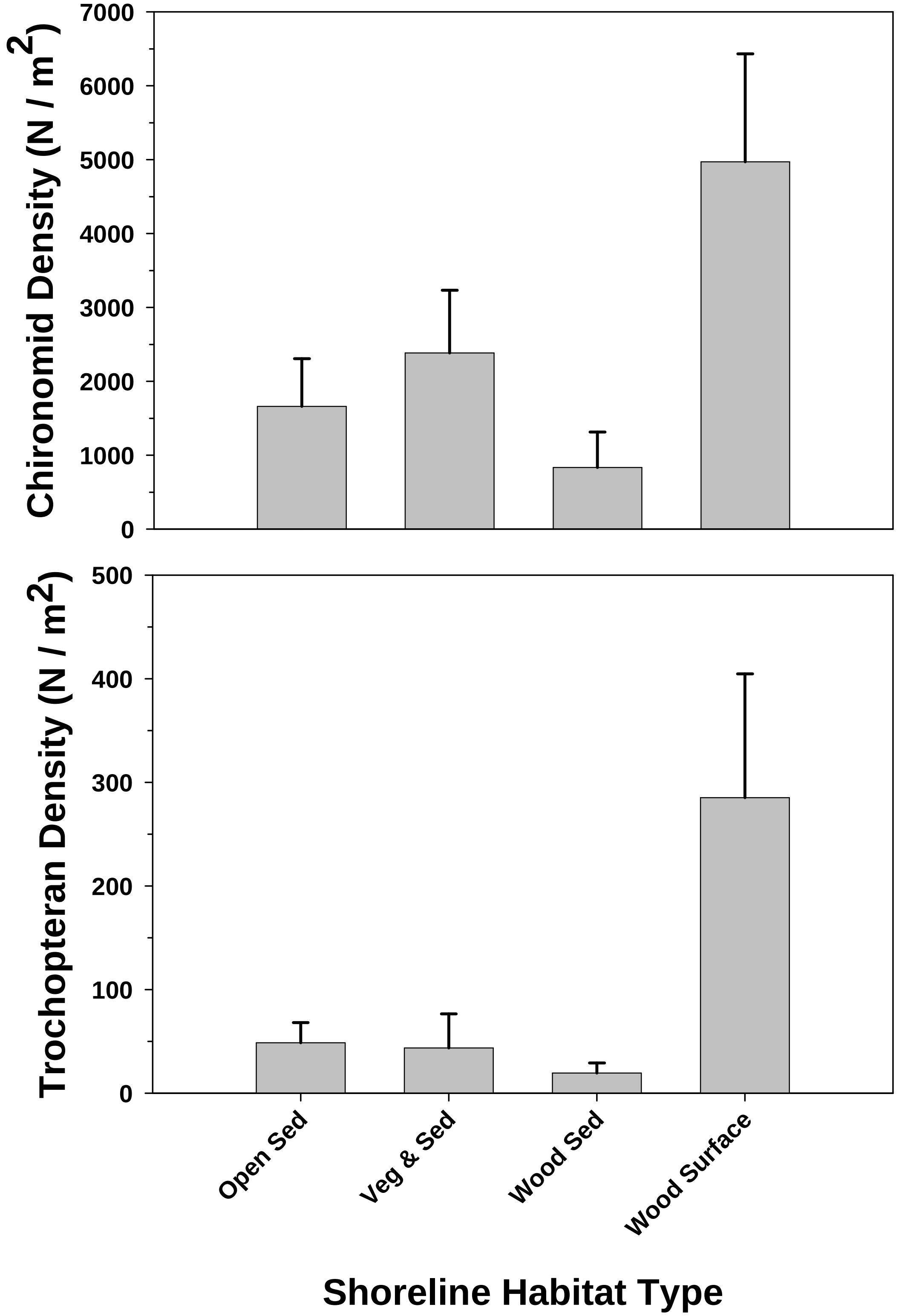

Figure 4-2: Mean density of macroinvertebrates of the family chironomidae (top panel) and Trichoptera (Bottom Panel) sampled from open sediment (Open Sed), vegetated sediment (Veg & Sed), wooded sediment (Wood Sed) and coarse woody habitat surfaces (Wood Surface) across two Illinois Lakes during August of 2009. Each bar represents an average of three sites of each category from each lake (total N = 6 samples per habitat type).

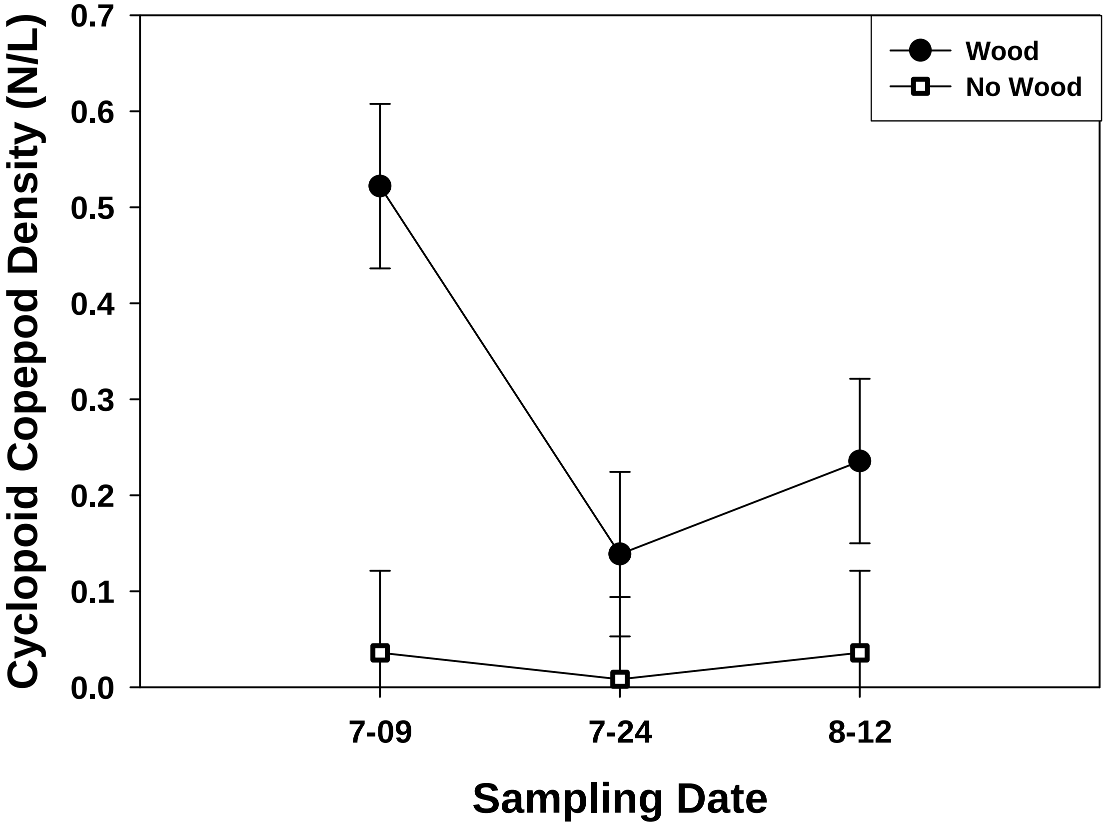

Figure 4-3: Mean density of cyclopoid copepods over time in tenth acre-ponds with (N=5) and without (N=5) coarse woody habitat additions sampled during summer 2008.

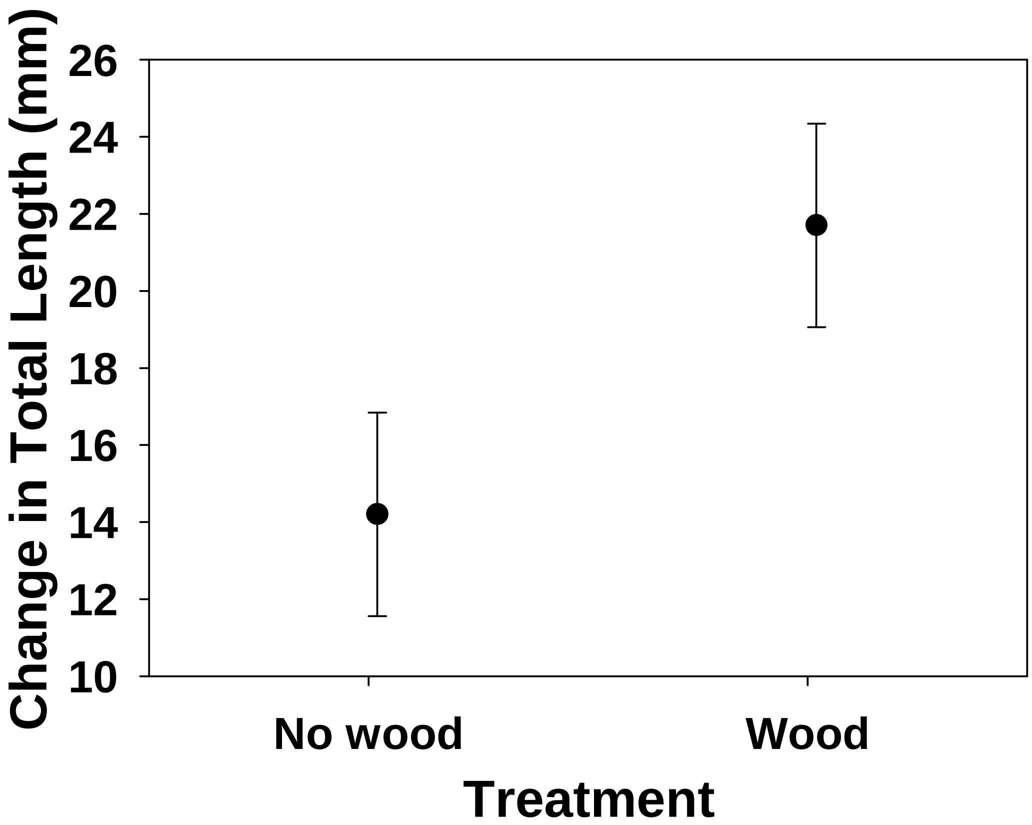

Figure 4-4: Mean growth (mm) of small bluegill from an overwinter pond experiment with two treatments. One treatment consisted of ponds where woody habitat was added and other treatment where no woody debris was added.

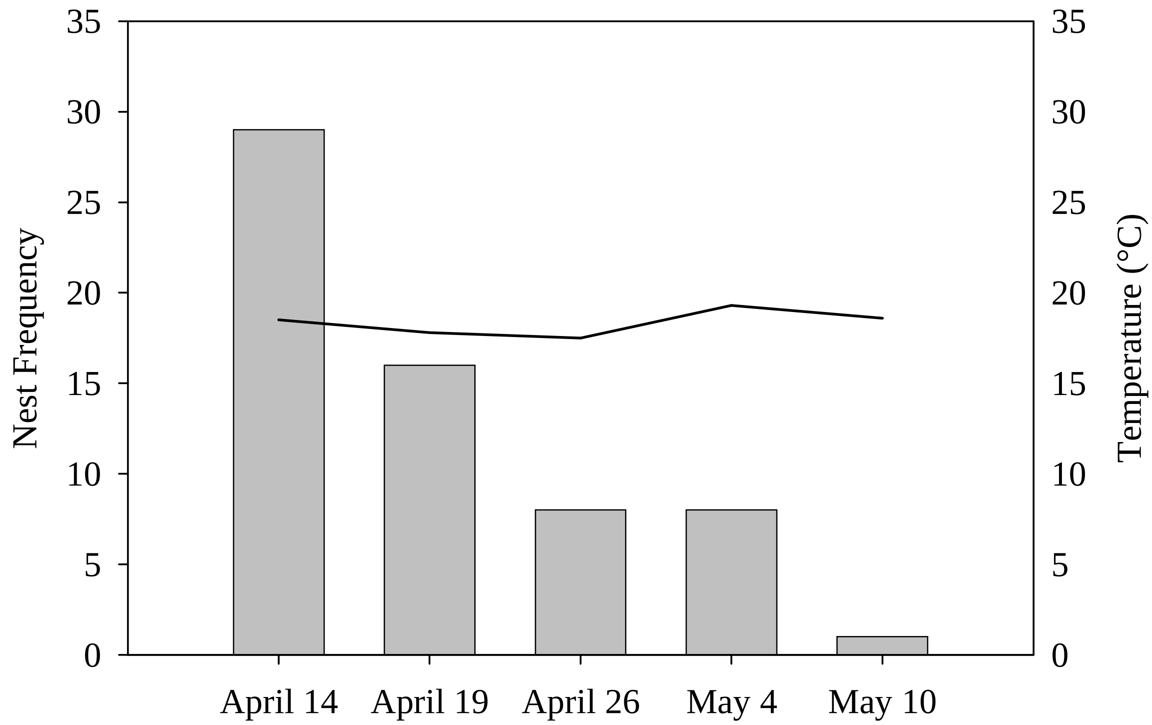

Figure 5-1: Nest frequency (bars) and water temperature (line) through time during spring 2010 in Lincoln Trail Lake.

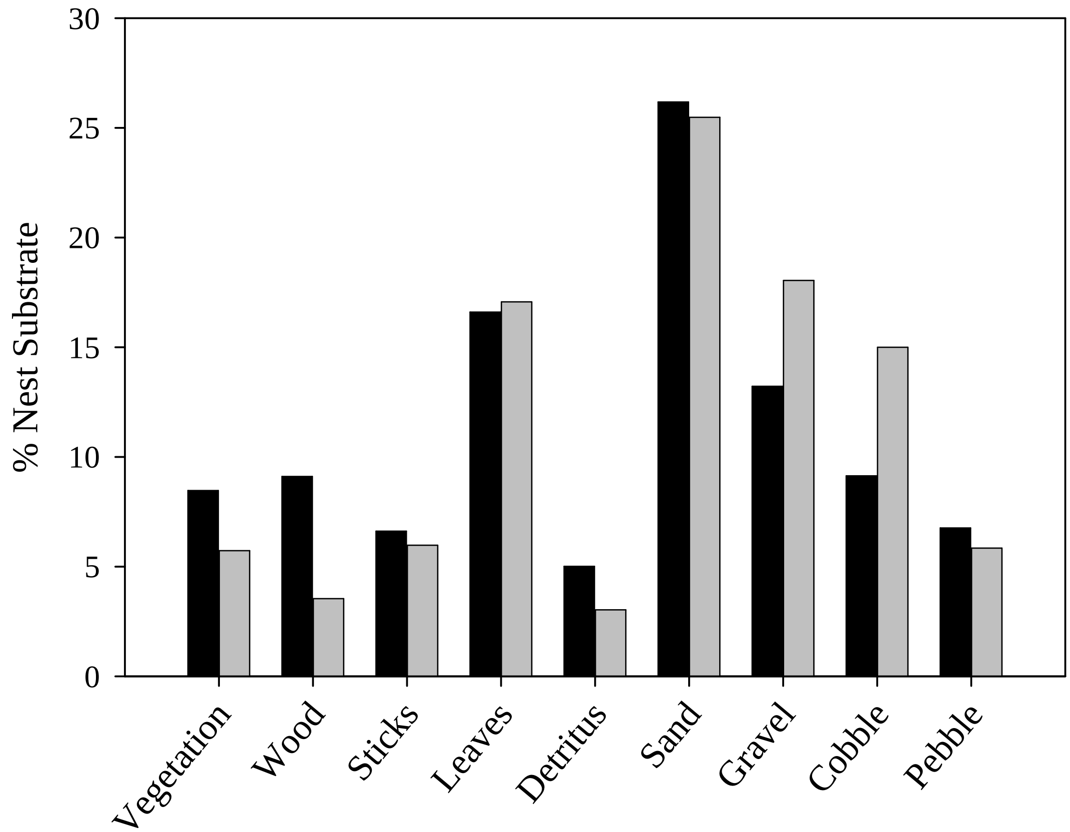

Figure 5-2: Composition of largemouth bass nest habitat in Lincoln Trail Lake with (light bars) and without (dark bars) potential nest predators.

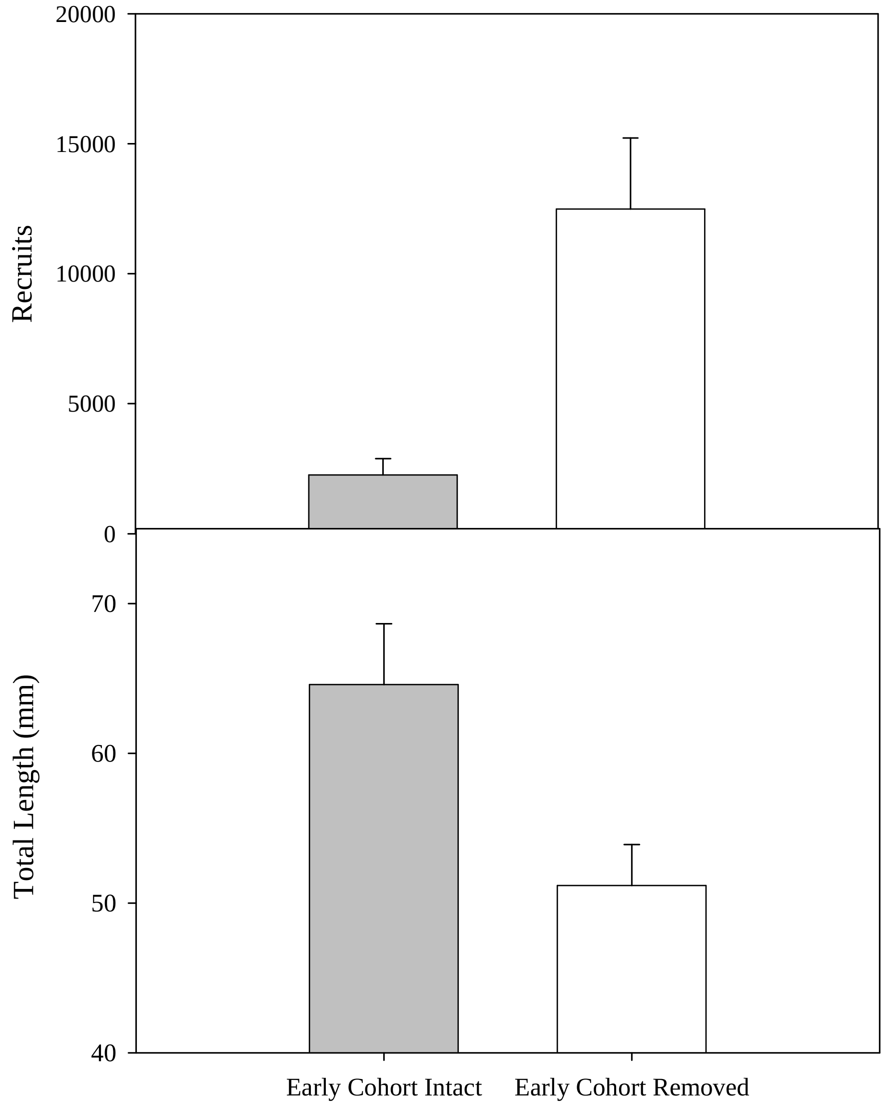

Figure 5-3: Manipulative pond experiment in which the early cohort had been removed (open bars) vs. left intact (black bars) resulted in differences in a) recruitment and b) total length (mm).

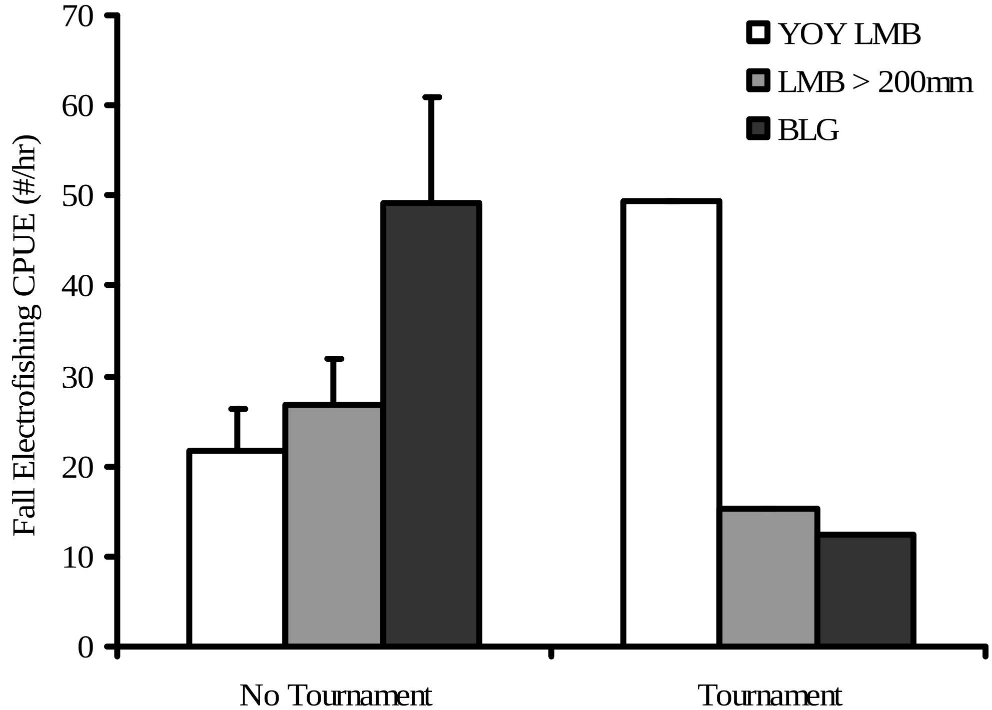

Figure 5-4: Catch per unit effort (CPUE) of young-of year largemouth bass (YOY LMB), largemouth bass larger than 200 mm (LMB > 200mm), and bluegill (BLG) from fall electrofishing samples performed at Ridge Lake. CPUE is the mean of years where spring tournaments were conducted (2007) and years with no tournaments (2006, 2008, and 2009).

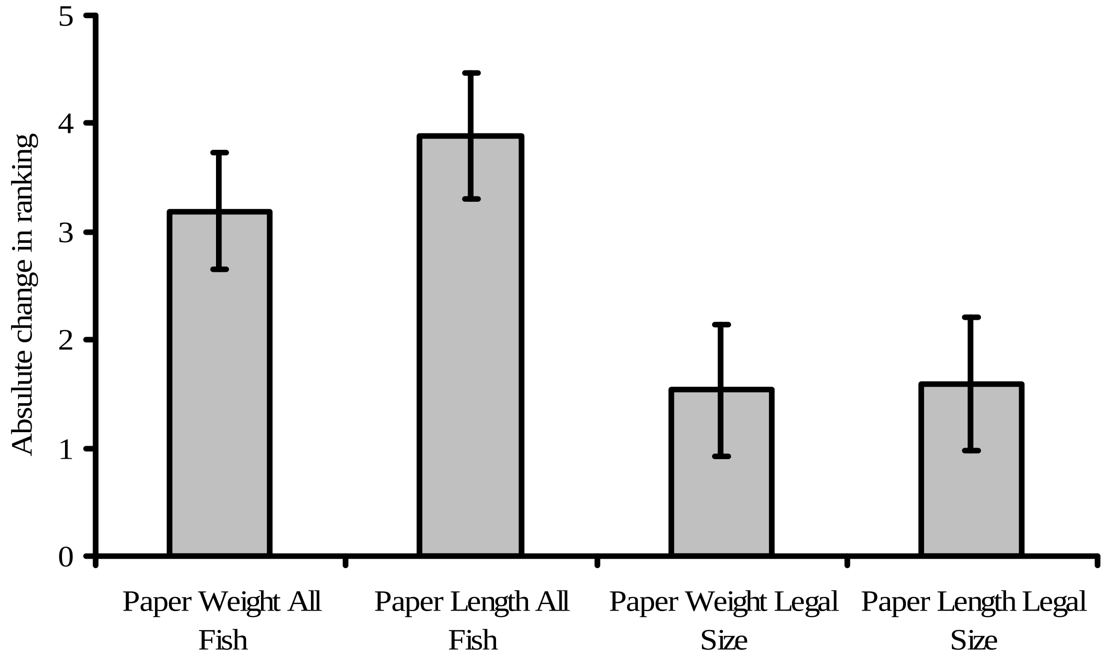

Figure 5-5: Mean absolute change in ranking from a typical weigh-in for 4 different paper tournament scenarios. The length of each fish caught was recorded by anglers to produce paper length. Length-weight regressions were used to convert paper length to paper weight. All fish refers to the cumulative of all fish caught by an angler, where legal size only included fish caught that were larger than the legal limit for the lake on which the tournament was held. Error bars represent the standard error.

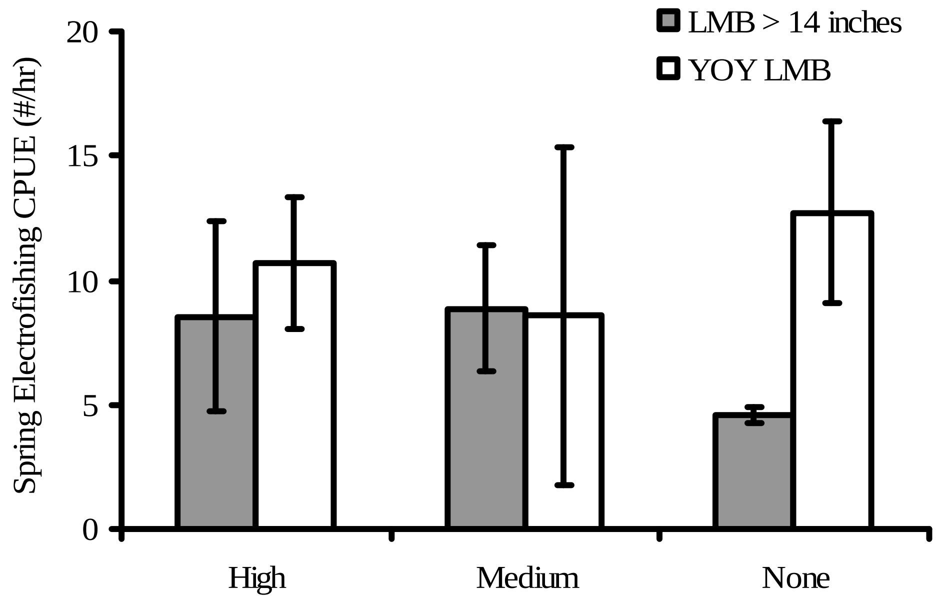

Figure 5-6: CPUE of adult largemouth bass (LMB > 14 inches) and young-of-year largemouth bass (YOY LMB) from spring electrofishing transects performed on 12 lakes with varying tournament angling pressure. The lakes were divided into High, Medium, and None based on tournament pressure and the mean CPUE is based on the 4 lakes in each category.

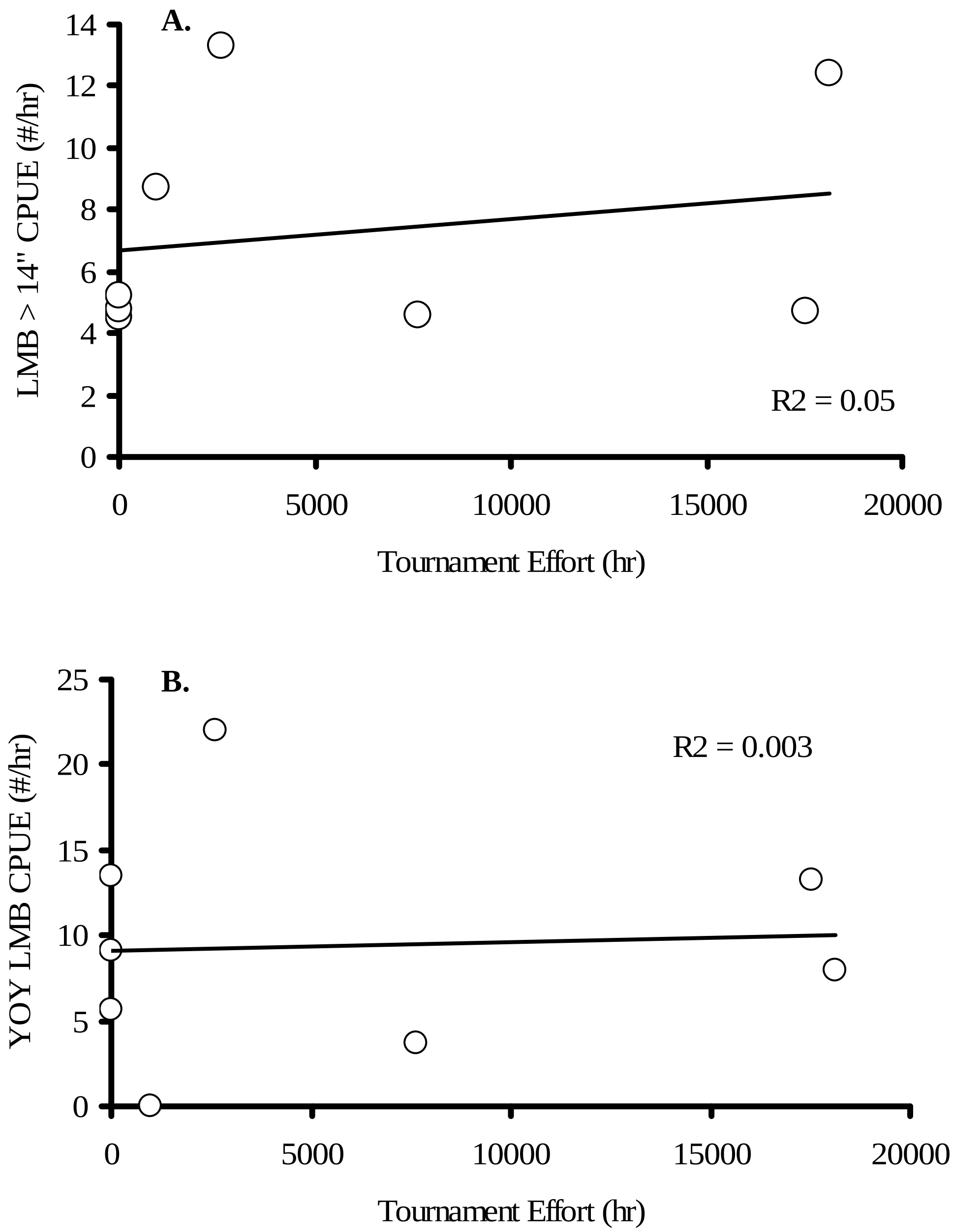

Figure 5-7: Relationship between tournament effort and (A.) relative abundance of largemouth bass greater than 14 inches in length and (B.) catch per unit effort of young-of-year largemouth bass from spring electrofishing samples. Effort is the total amount of tournament angler hours for each lake.

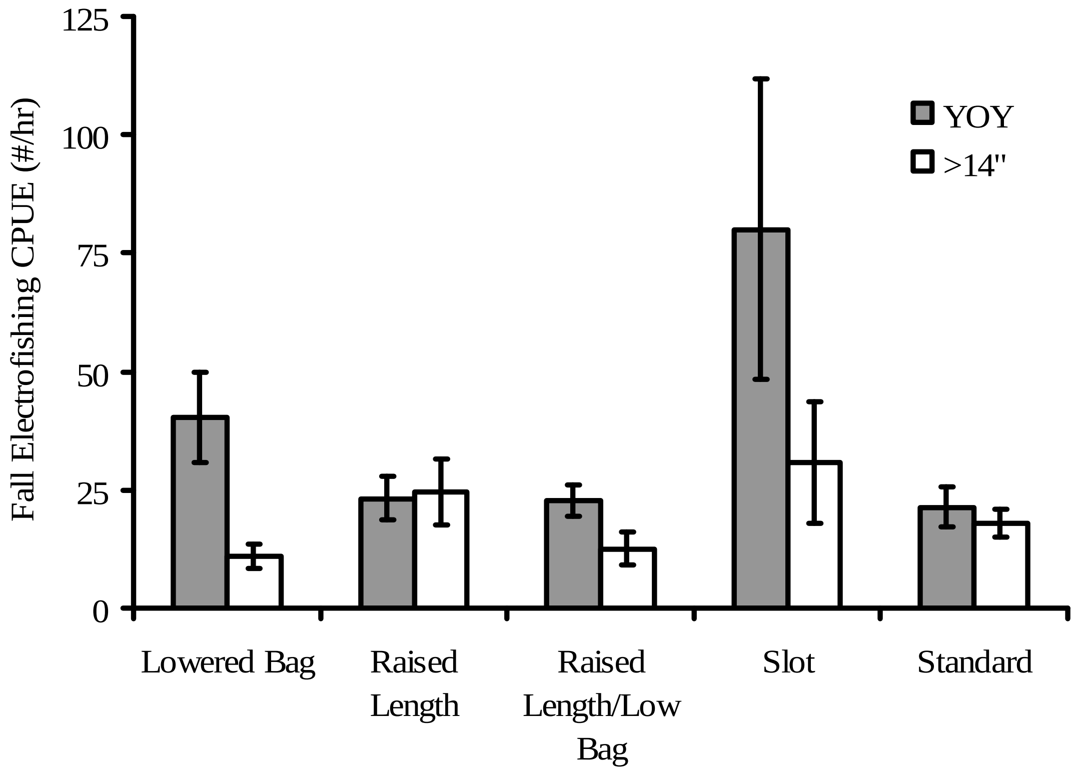

Figure 6-1: Catch per unit effort of young-of-year and adult largemouth bass greater than 14 inches from fall AC electrofishing transect performed by DNR biologists in 2007. Lakes were categorized by their fishing regulation into Lowered Bag, Raised Length, Raised Length/Lowered Bag, Slot, and Standard.

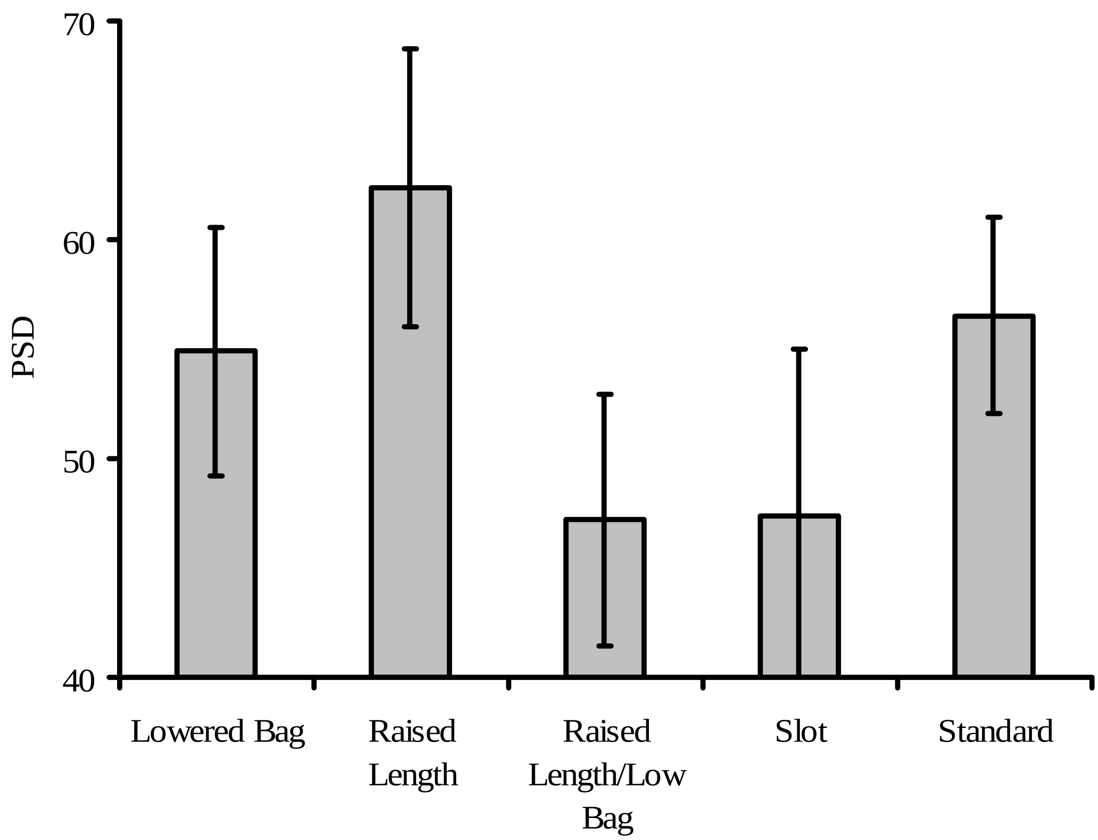

Figure 6-2: Proportion stock density (PSD) calculated from numbers of fish captured in fall AC electrofishing transect performed by DNR biologists in 2007. Lakes were categorized by their fishing regulation into Lowered Bag, Raised Length, Raised Length/Lowered Bag, Slot, and Standard.